



# **Goddard Space Flight Center Colloquium Presentation**

**April 30, 2002**

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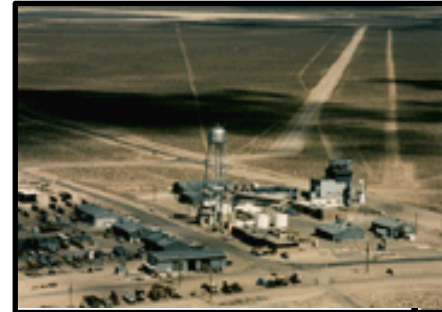
## **Space-Relevant S&T Programs at Sandia National Laboratories**

**A. D. Romig,  
Vice President for Science & Technology and Partnerships  
& Chief Technology Officer  
Sandia National Laboratories  
Phone: 505-844-8358  
E-mail: [Adromig@sandia.gov](mailto:Adromig@sandia.gov)  
FAX: 505-284-3166**

# **Sandia National Laboratories, a DOE National Laboratory, is located at six major sites**



**Albuquerque, New Mexico**



**Tonopah Test Range,  
Nevada**



**WIPP, New Mexico**



**Yucca Mountain,  
Nevada**



**Kauai Test Facility, Hawaii**



**Livermore, California**



# Sandia — in round numbers

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- **7,600 full-time employees**

- ~6,600 in New Mexico

- ~1,000 in California

**600 buildings, 5M square feet**

**1,400 Ph.D.'s, 1,700 Masters**

- 55% engineering

- 33% science and mathematics

- 12% computing and other

- **Annual budget \$1.8B (FY02)**



# Sandia is a National Security Laboratory

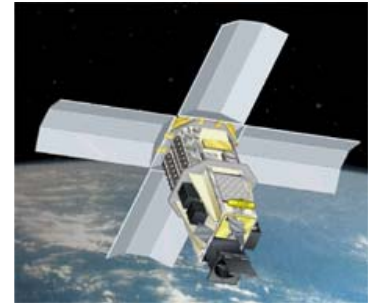
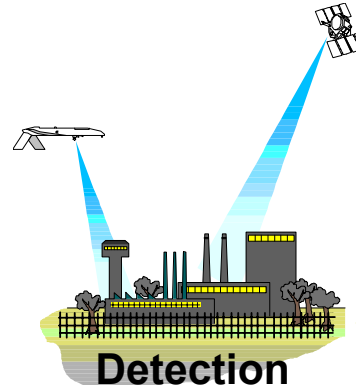
## Nuclear Weapons



**Safe, Secure,  
Reliable Weapons**



## Nonproliferation & Materials Control



**Surveillance**

## Energy & Critical Infrastructures



**Energy**



**Information**



**Transportation**

## Emerging Threats



**Architectural Surety**

**Anti-crime  
and anti-  
terrorism  
technology**



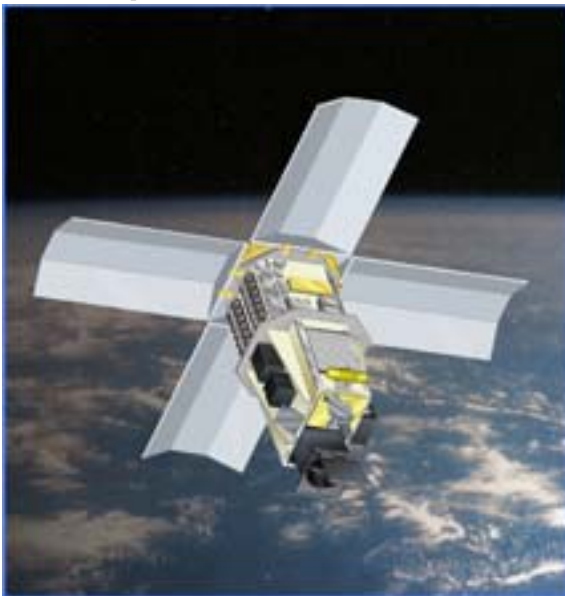
**Smart Weapons**





# Remote detection and characterization of terrestrial features and activities is a key Sandia mission

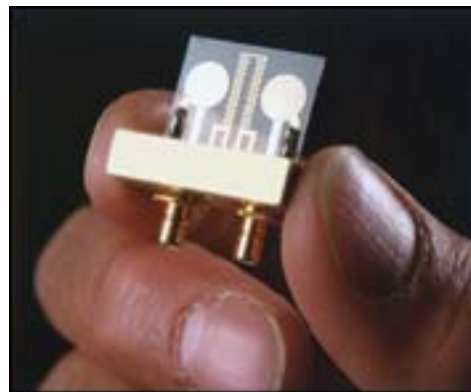
*MTI (Multispectral Thermal Imager  
Experimental Satellite)*



**Facility Detection and  
Characterization**

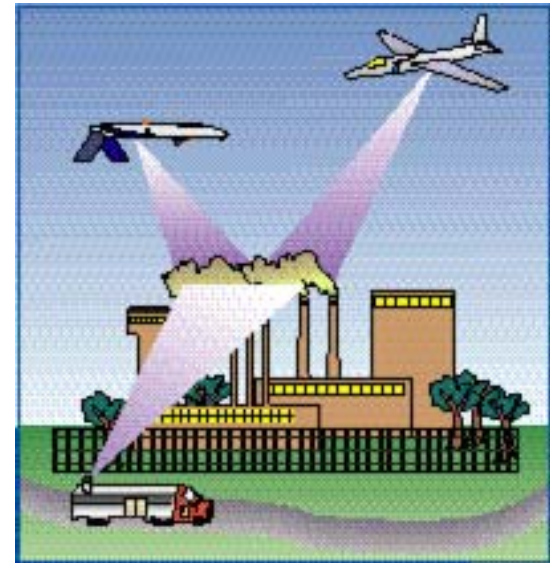


*Chemical Microsensor*



**On-site Effluent Detection  
and Characterization**

*CALIOPE (Chemical Analysis by Laser  
Interrogation of Proliferant Effluents)*



**Remote Effluent Detection  
and Characterization**



# Sandia's Science and Technology Strategic Management Unit

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## Strategic Objective:

**We will pursue**

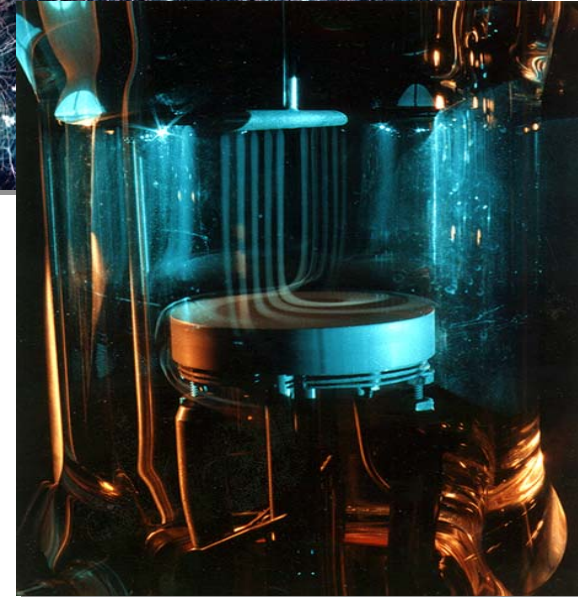
**“science with the mission in mind”**  
thereby providing solutions and  
options for the customers of Sandia’s  
current and future business units.

Executive Leadership: Al Romig

Internal Customers: Lab Director and SBUs

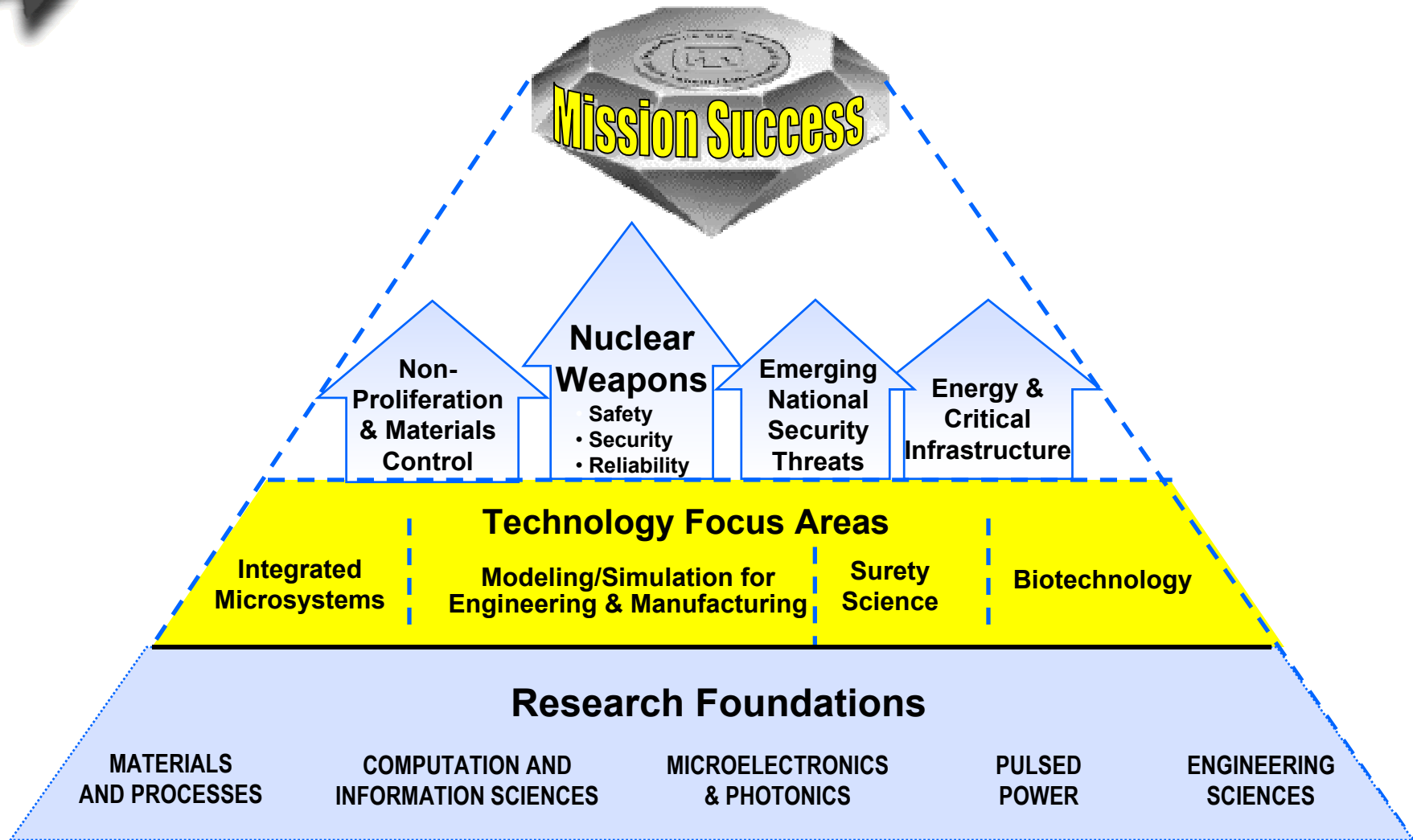
Primary External Customers: Industry, NASA, DOC, NIH, NSF

	<u>External</u>	<u>Internal</u>
FY01 Revenue/Costs	\$47M	\$330M
Direct SNL Labor:	123 FTEs	900 FTEs



# Research and Technology

## Our most direct link to our missions



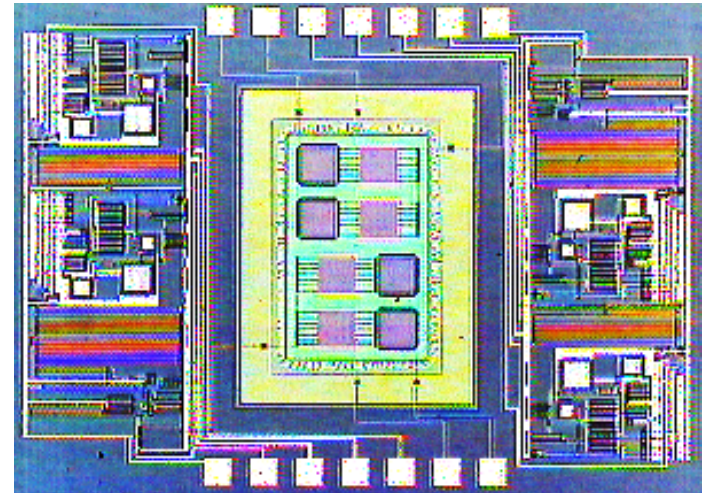


# Electronics for the 21st Century:

## *Inventing the Future, and Making it Happen*

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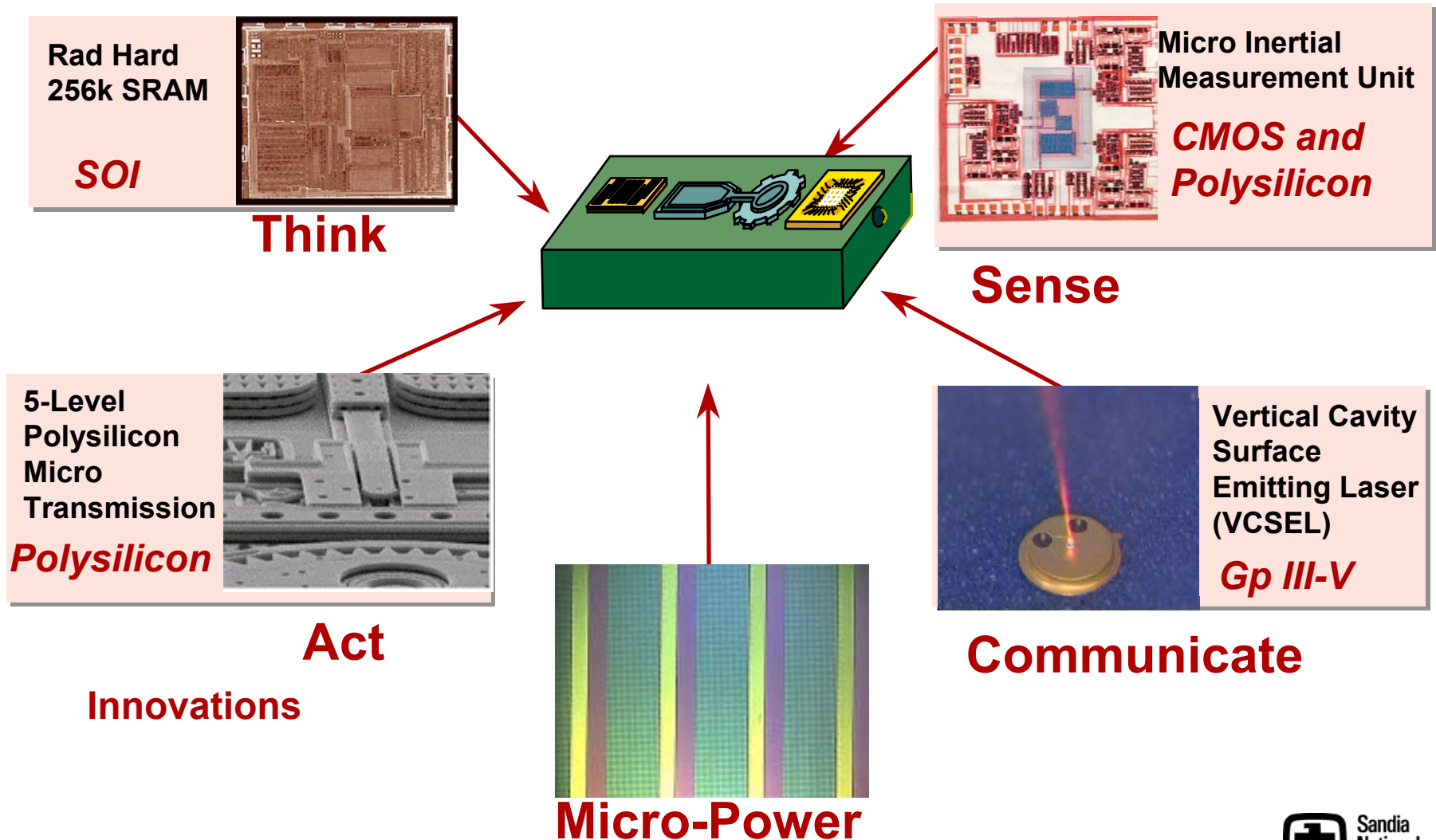
- The next leap in function of Integrated Circuits will involve more than just packing more transistors on the chip
- It will involve the building of new microscopic structures along side the transistors, giving the chip the ability to
  - Sense,
  - Think
  - Act
  - Communicate



**This technology will impact our lives in this century as profoundly as the IC did in the last.**

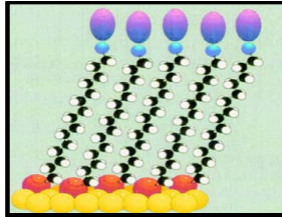


# Microsystems provide **new dimensions** of functionality “transforming” Micro**electronics** into Micro**systems**

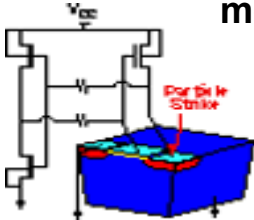


# Technology Focus Area: Integrated Microsystems

**Sense**



self-assembled  
monolayers

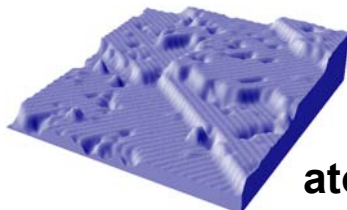


radiation  
physics

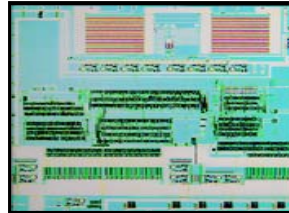


strained-layer  
semiconductors

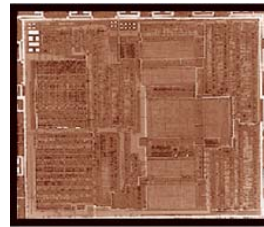
**Act**



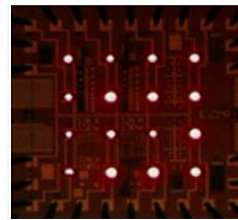
atomic  
microscopy



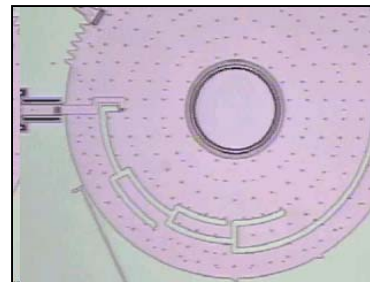
smart  
sensors



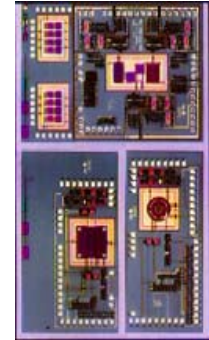
custom  
microprocessor



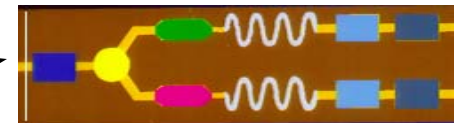
optical  
communication



-MEMS  
actuators



**Micro-navigator**

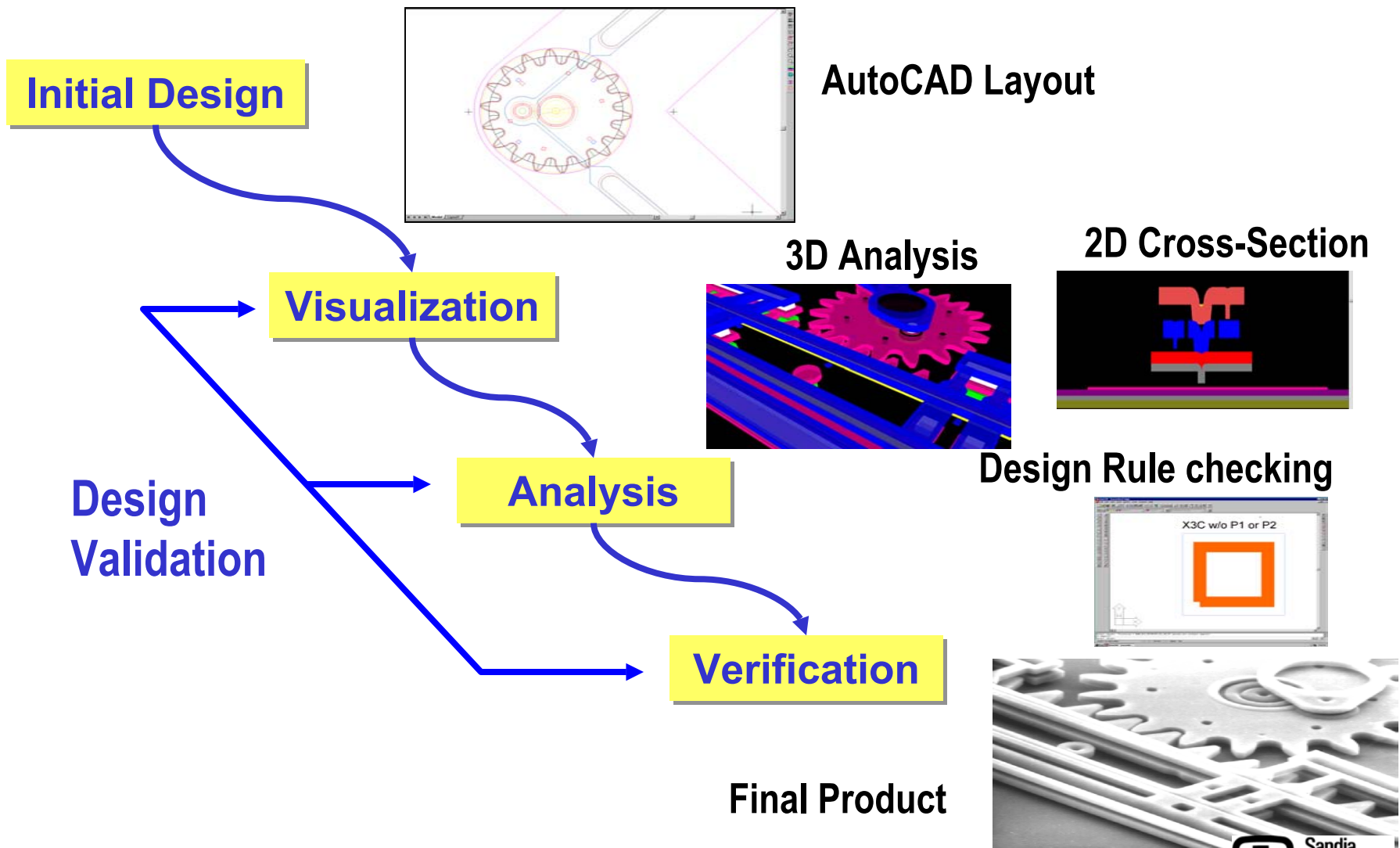


**Chem Lab-on-a-Chip**



**Micro-surety  
Device**

# MEMS Design - Process flow

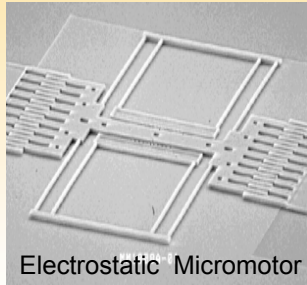




# SUMMIT™

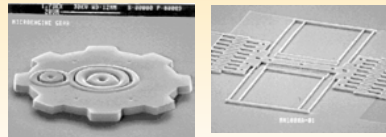
## (Sandia's Ultra-Planar Multi-Level MEMS Technology)

### 2\*-Level

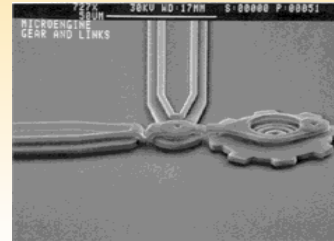


Electrostatic Micromotor

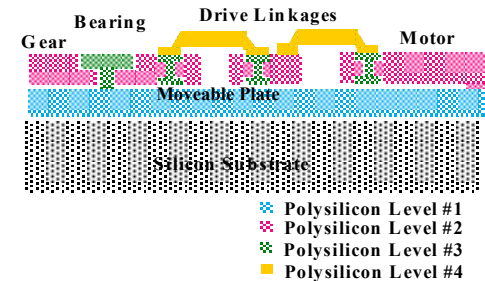
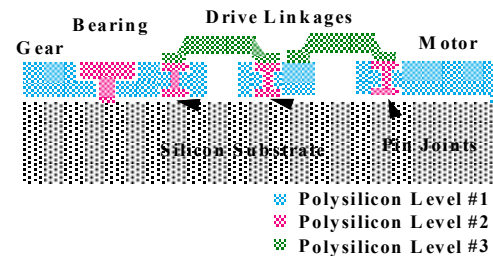
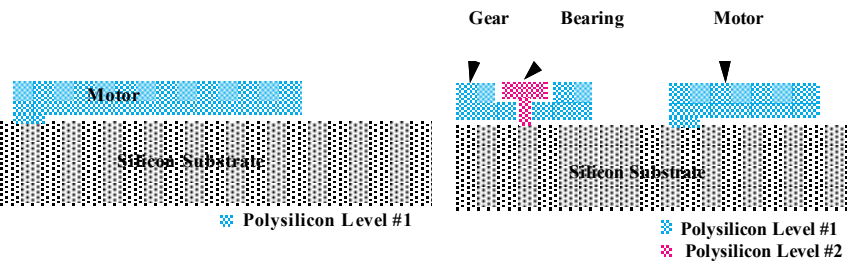
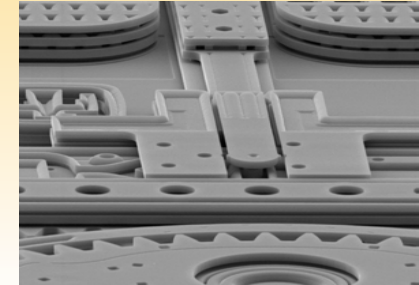
### 3-Level



### 4-Level



### 5-Level

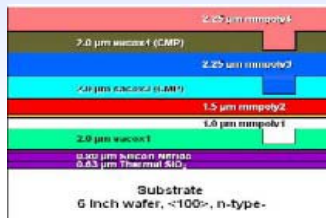


### Sensors

### Advanced Sensors Simple Actuators

### Advanced Actuators

### Complex Systems



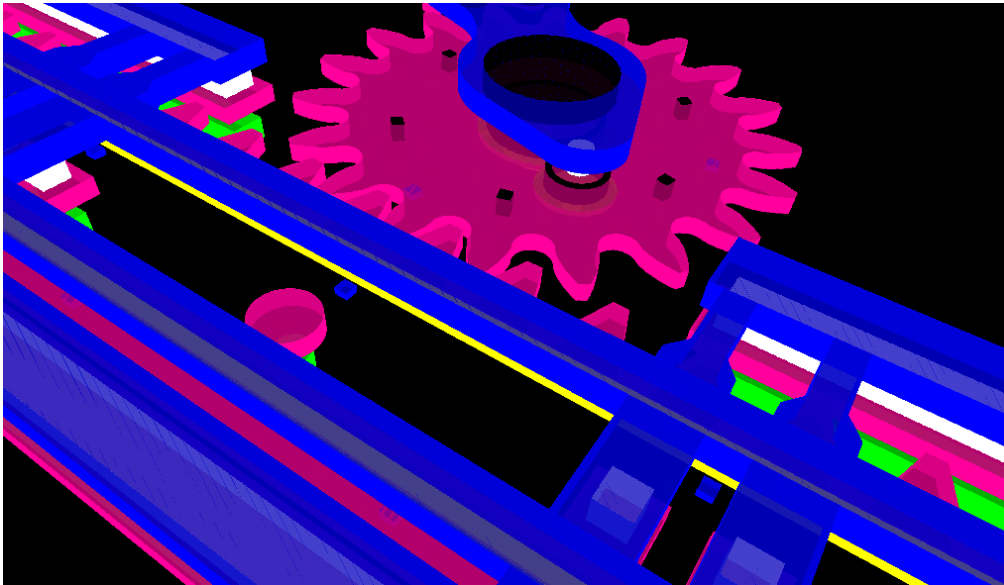
CMP



# Critical Microsystem Design Realization Needs

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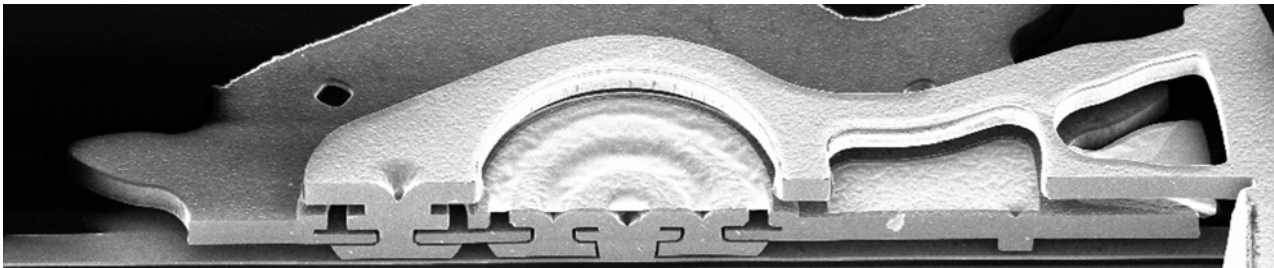
## Process-Based 3-D Visualization



Accurate process model  
resulting in physically  
correct shapes

Integrated with layout  
tools

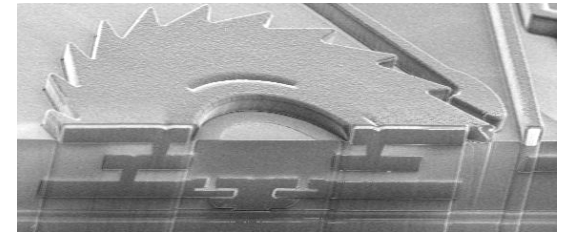
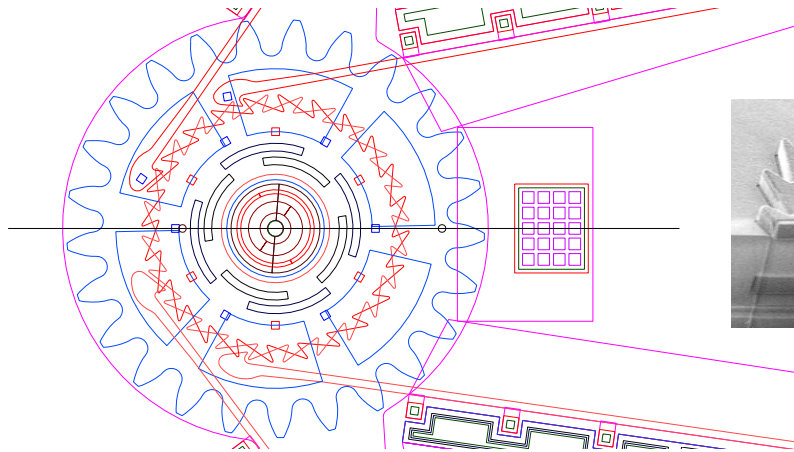
“Designer-Friendly”  
navigation interface



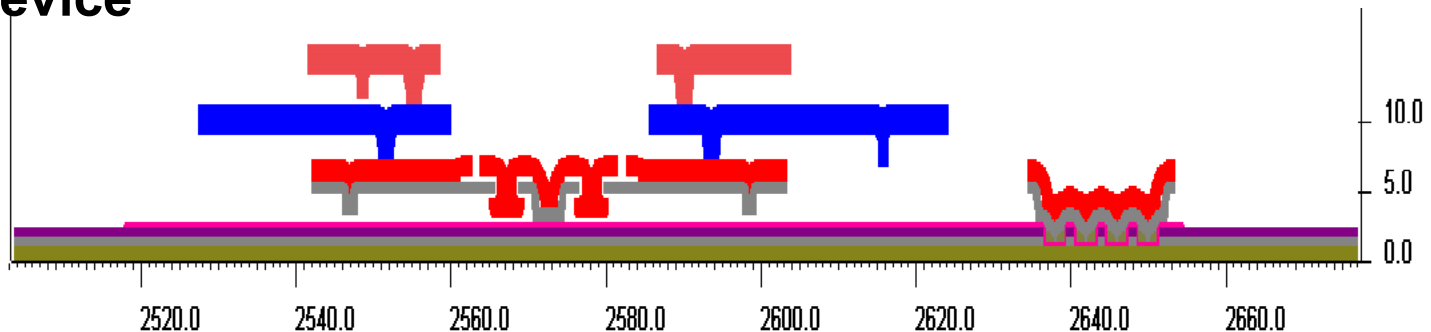
# SUMMiT™ Process Cross-sections: Released Structure (Double Ratchet)



**SEM perspective  
view of fabricated  
device**



**FIB Cross-section  
of fabricated  
device**



# RF MEMS

Integration for performance, size and cost



**Conformal  
Phased-  
Array  
Antennas**



**Dipole Array**

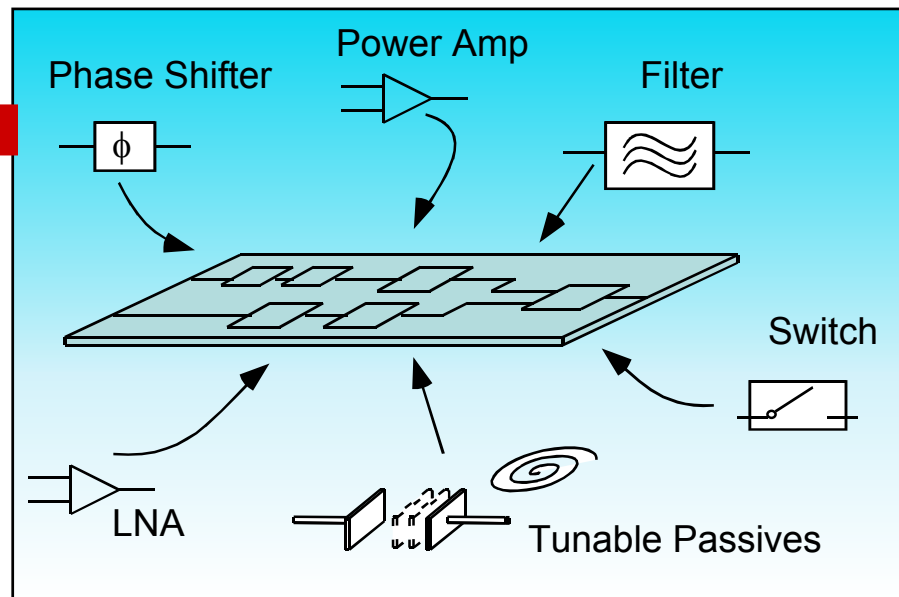
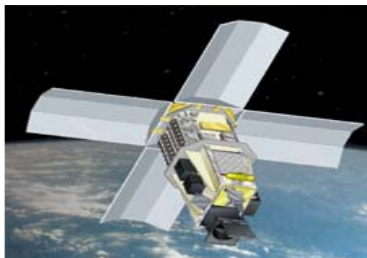


**Fusible Radar  
for Weapons**



**Satellite  
Communications**

**Surveillance**



**Misc. Applications:**

- Micro-implantable Systems
- UAV's
- Portable ground based communications

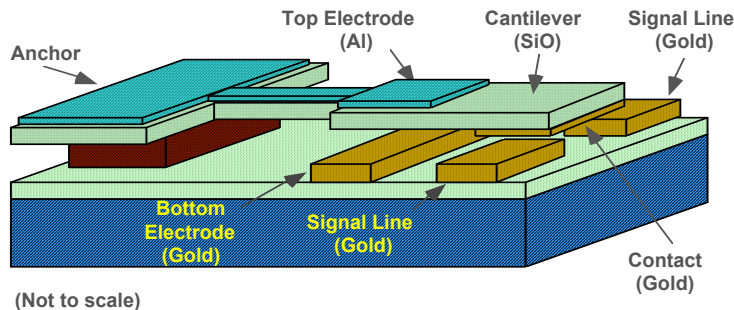
Technology



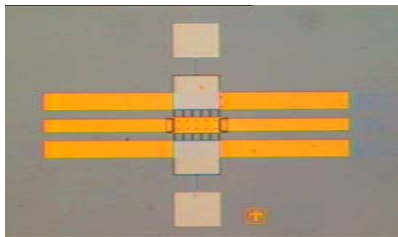
Sandia  
National  
Laboratories

# RF MEMS Technology

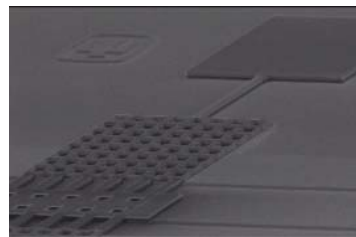
## GaAs post-processing



## Switch Diagram



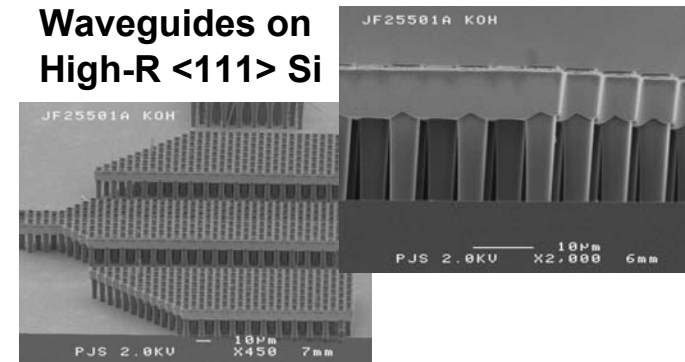
Switch & Waveguide



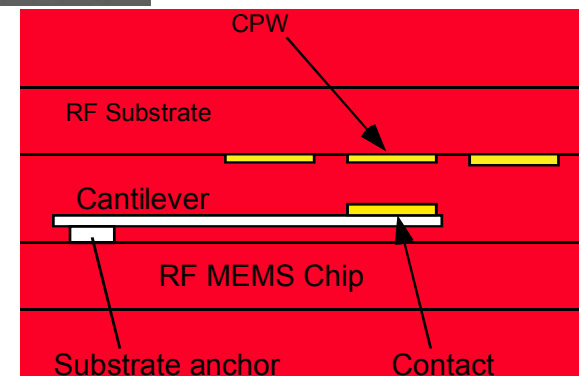
Switch

## High-Resistivity Si Processing

### Waveguides on High-R <111> Si



### Flip chip bonding



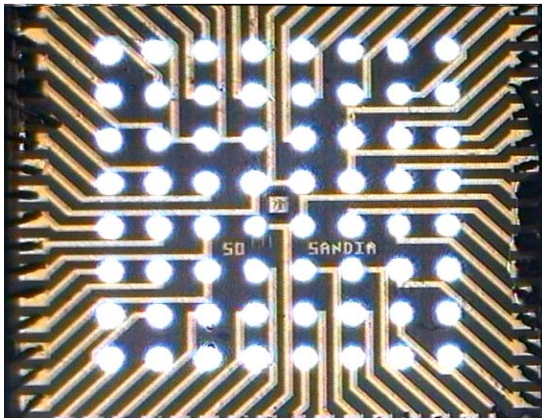
## Advanced Concepts

- Increased Integration of MMIC's
- Low temp. processing

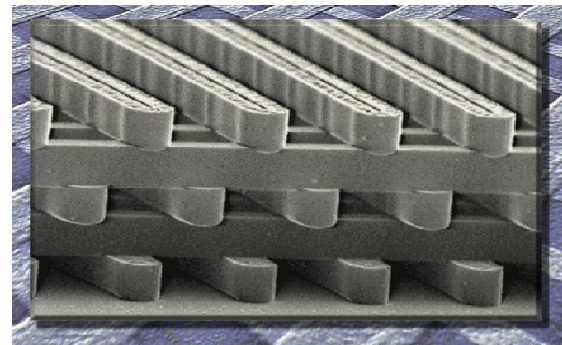
- GaAs micromachining
- Bulk material processing



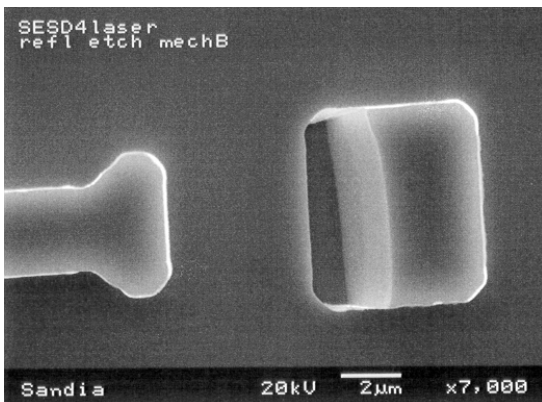
# SNL's Principal Photonic Communication Building Blocks



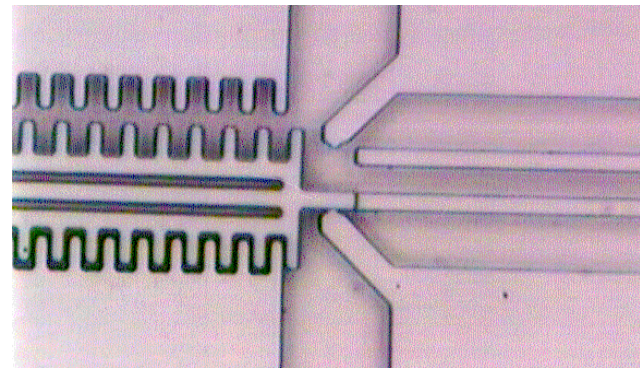
**Light Sources**



**Waveguides**



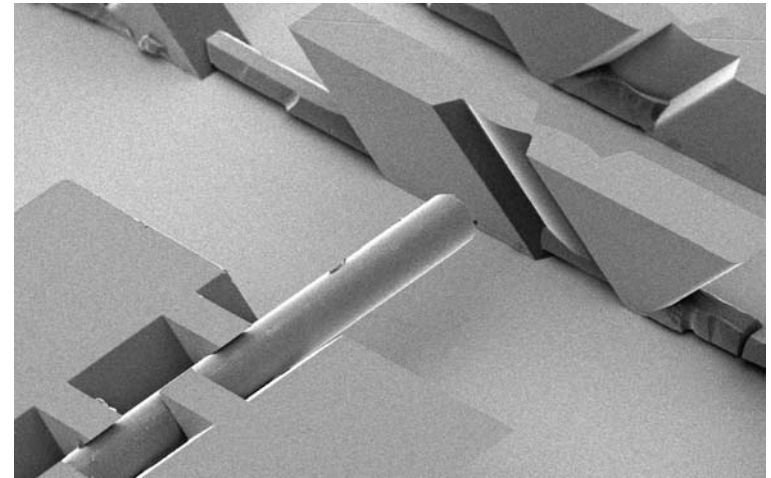
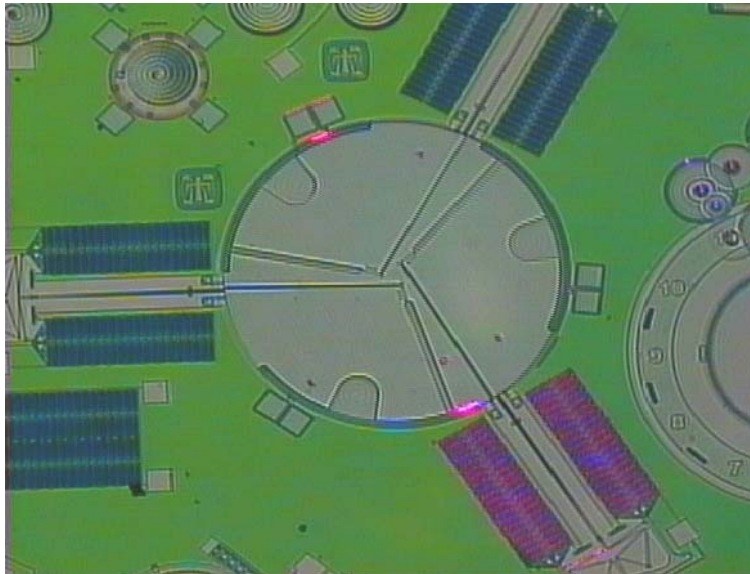
**Optical Receivers**



**Optical Switches**

# Optical MEMS

**Free-space optical switching is currently one of the hottest applications of MEMS.**

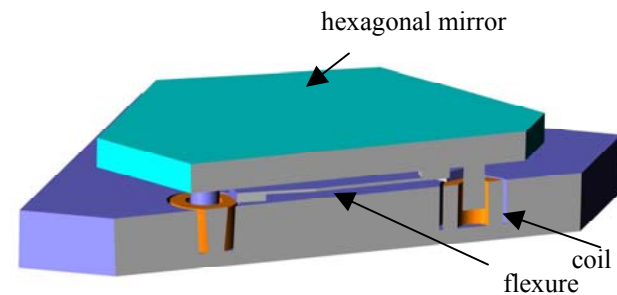


Single fiber with two optics in background.  
(PMMA: Clear plastic)



## Communications

- Laser Beam Scanning
- Environmental Sensing
- Wavefront Correction

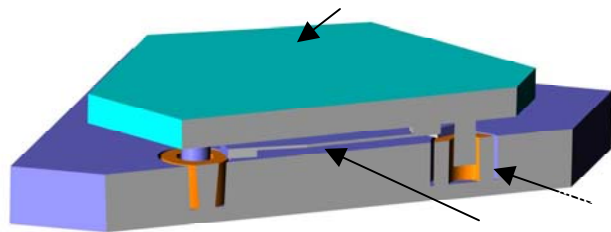


2mm

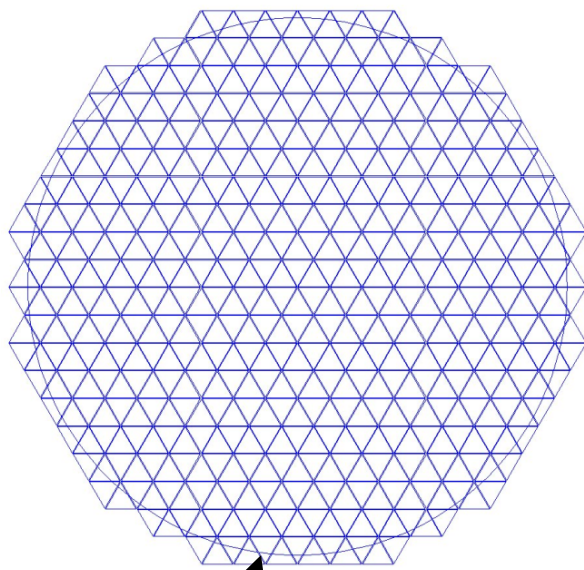
PL

Adaptive  
Optics

# Adaptive Optics



2mm



35 mm  $\phi$  array  
positionable

## Wavefront Correction

Changing Phase of Wavefront by increasing the path length

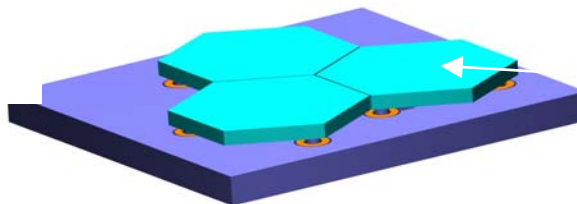
Correcting Atmospheric Turbulence  
(Astronomy-twinkling)

Focusing the unfocused



## Deformable thin film mirror (one surface)

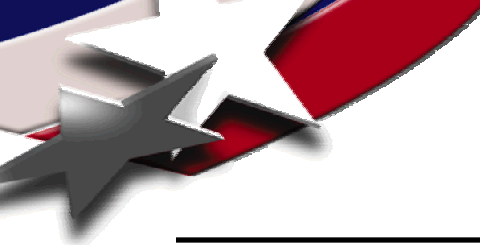
- Combines bulk micromachining and surface micromachining
- laser based communications
- biomedical imaging
- laser welding
- terrestrial imaging



## Segmented Mirrors

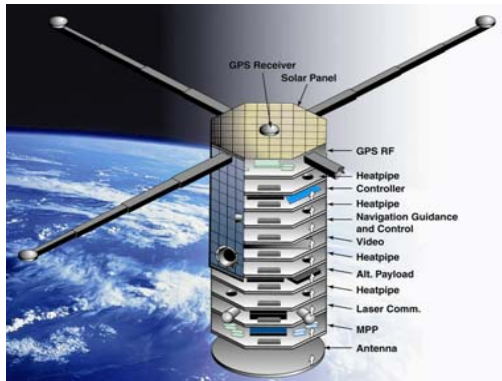
Tip and tilt and vertical movement



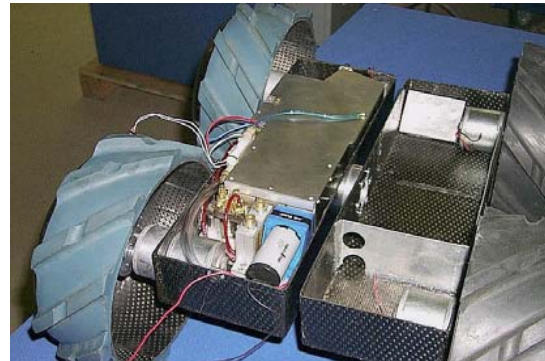


# Micro-Power Sources:

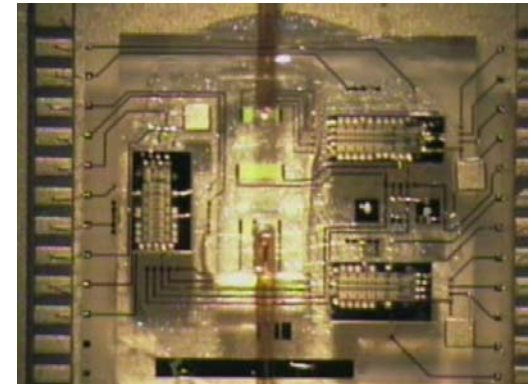
## The Microsystem Revolution requires advances in micro-power source technologies



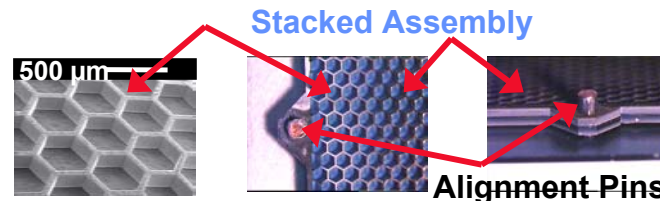
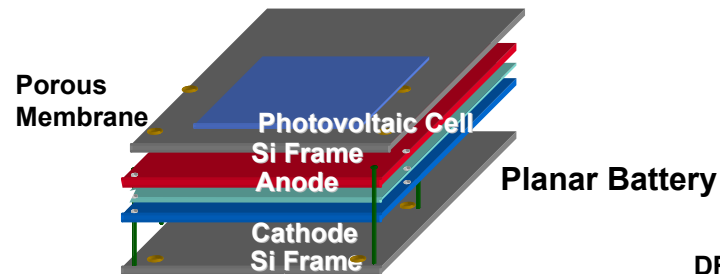
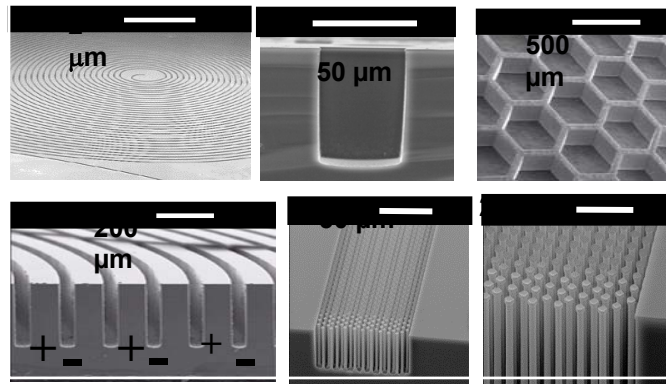
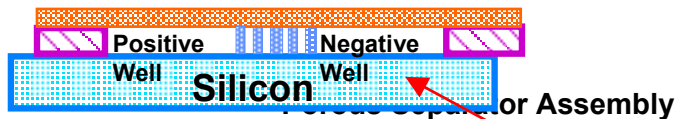
**Nano-Satellites**



**Micro-Robots**



**Chemical and Biological Sensors**



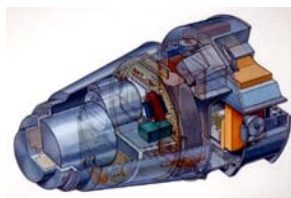
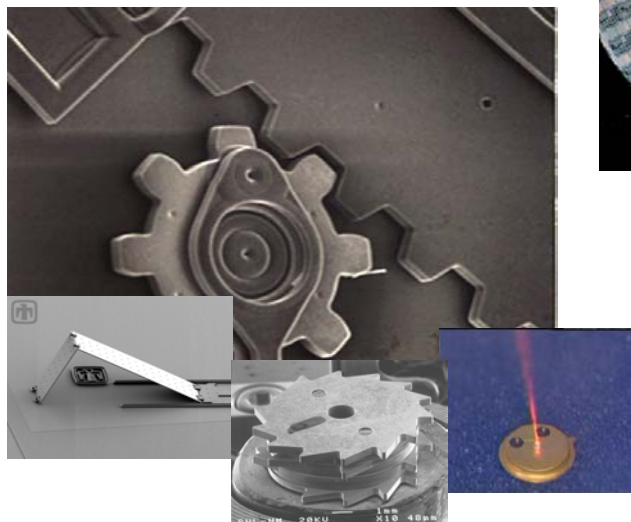
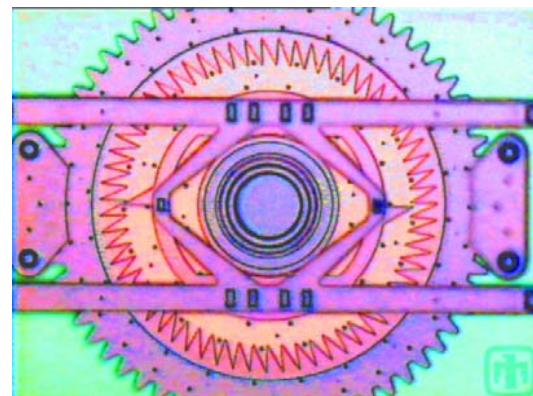
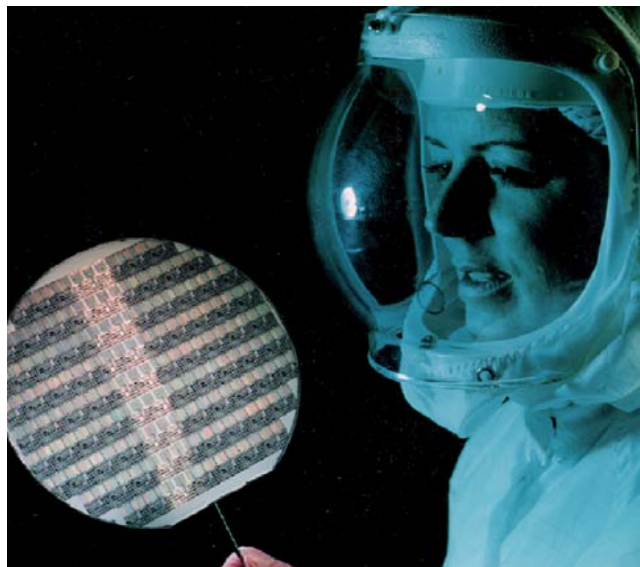
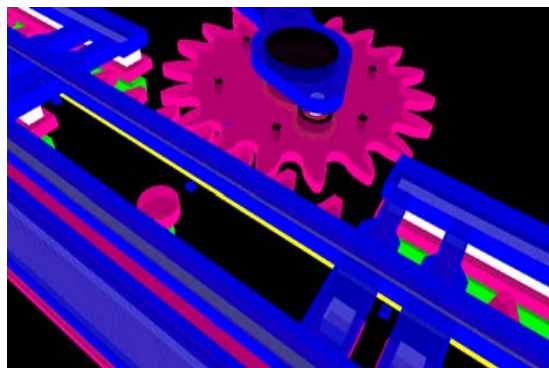
DRIE honeycomb well assembly for containment of positive and negative electroactive materials.

Technology





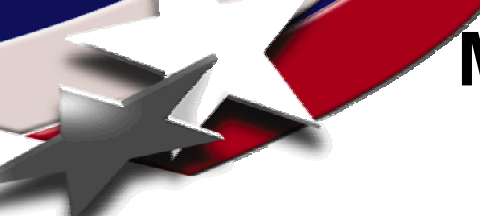
# MESA - Microsystems and Engineering Sciences Applications



Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.





# MESA's scope was determined in the context of a system solution

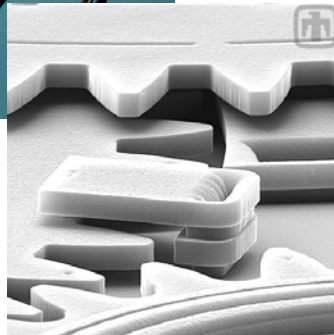
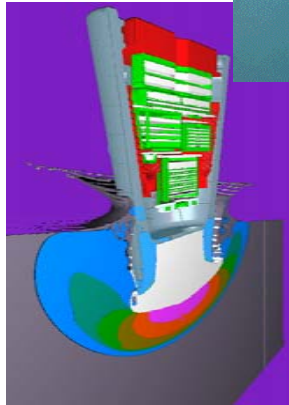
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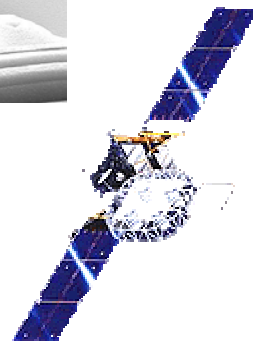
**The Nation's Brightest Scientists  
and Engineers**



**Using the Most Advanced Design and  
Simulation Tools**



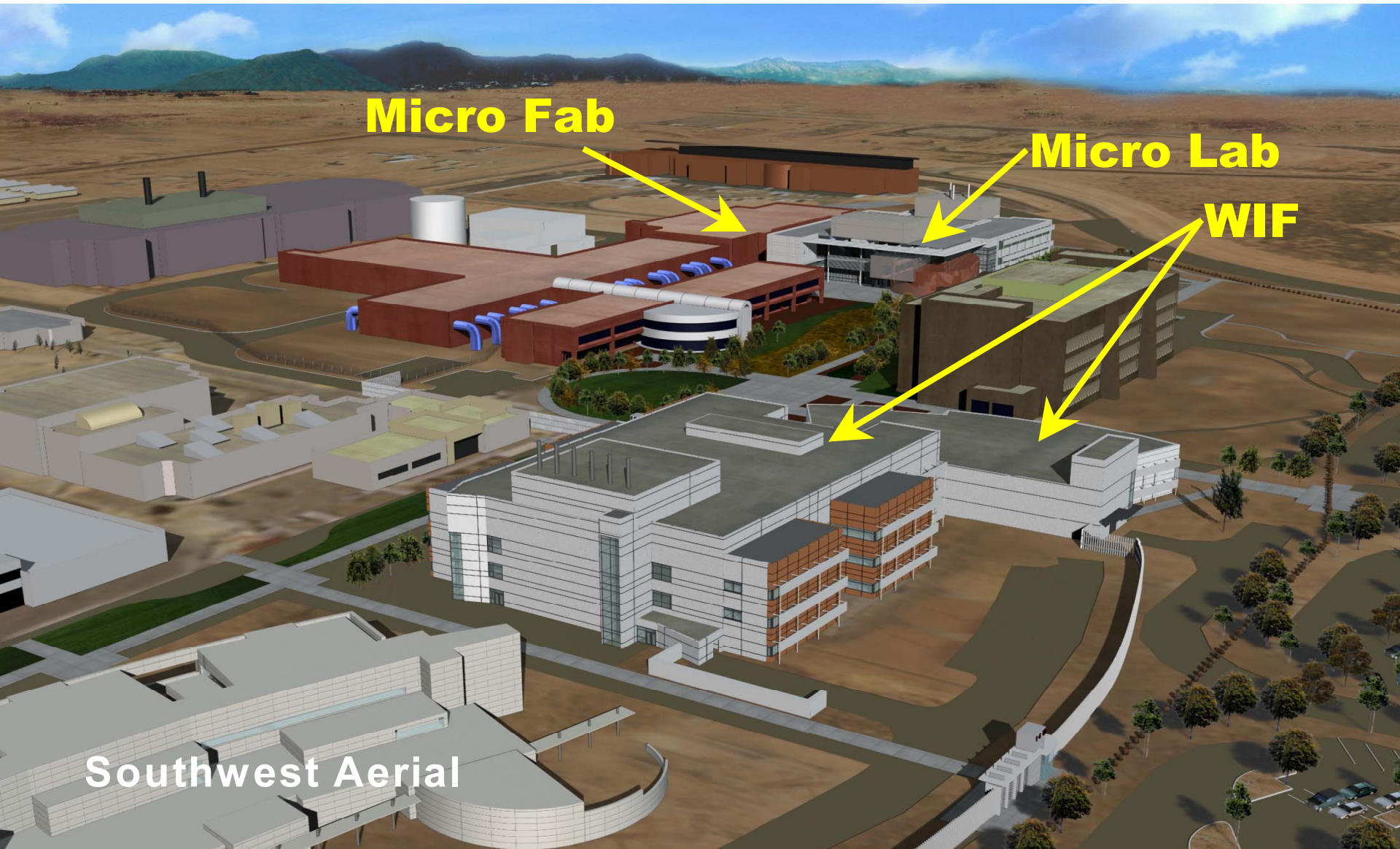
**And The Most Advanced  
Microsystem Technologies**



**To Positively Impact  
National Security  
*Now and in the Future***

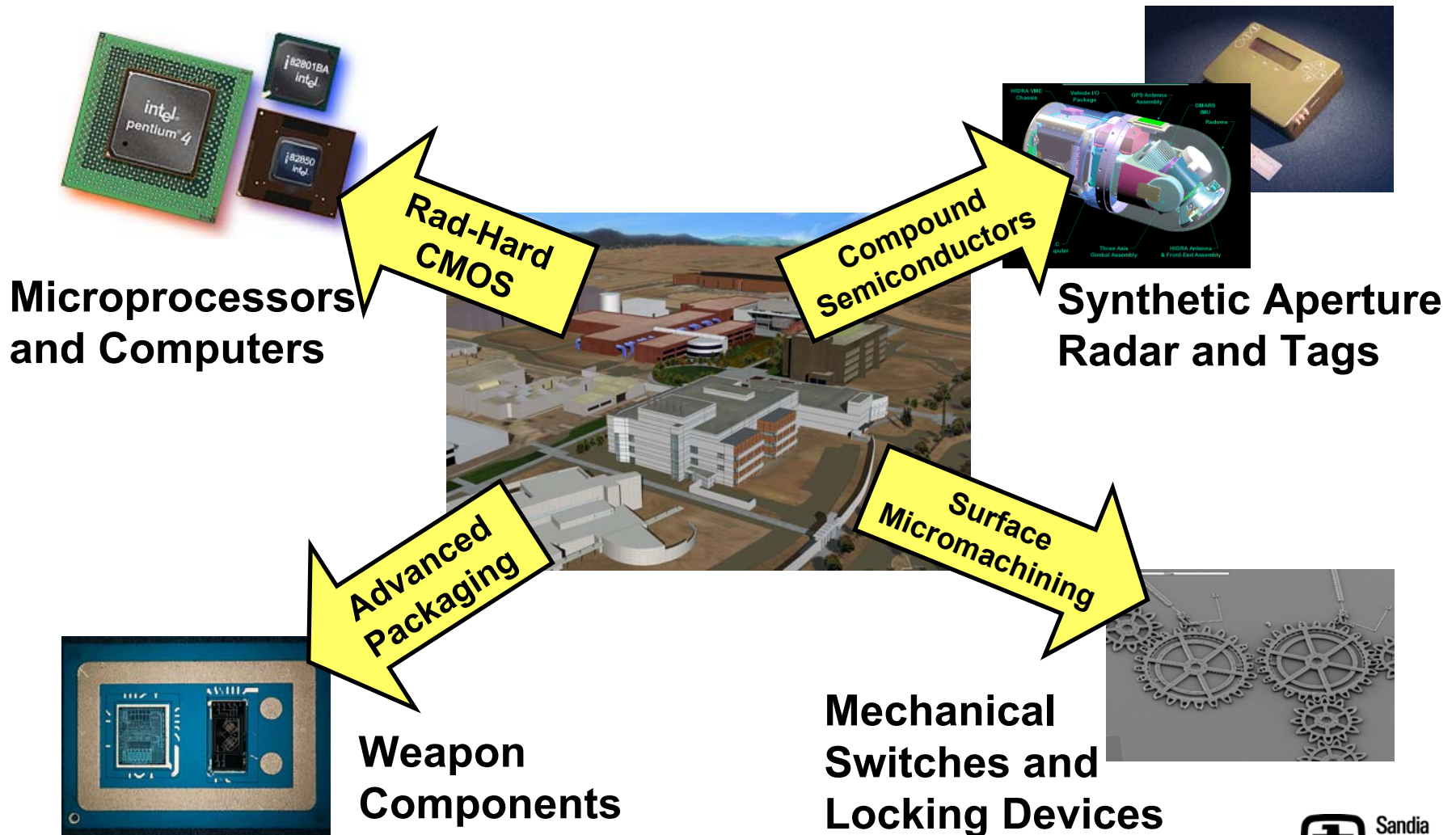


# Southwest Aerial View of the MESA Complex



**MESA is the Cornerstone of the Strategy to Meet our Mission Needs**

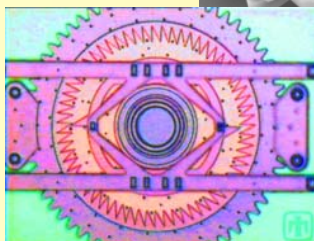
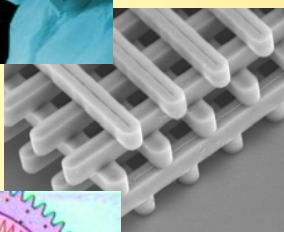
# Microsystems technologies are advanced through flagship products





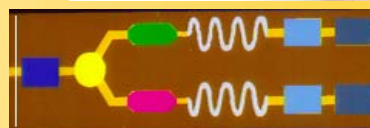
# Impact of S&T - Today and Tomorrow

**MESA**

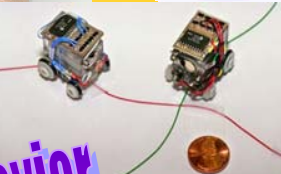


**Physics-Life**

**S&T**



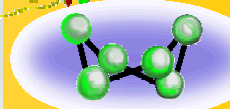
**Complex/Emergent behavior**



**Bio?**



**Nano?**



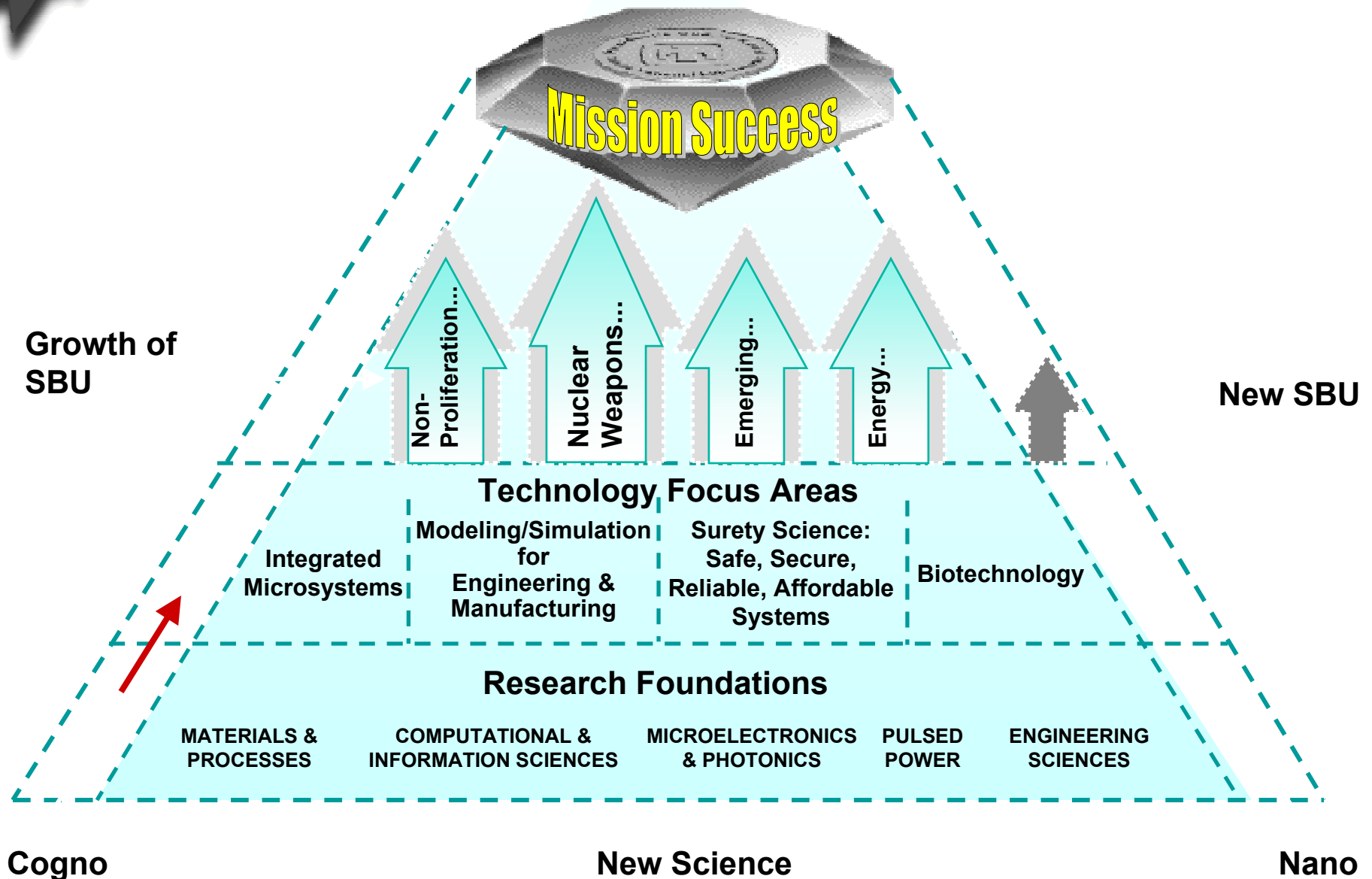
**Info?**

**Cogno?**

**FUTURE**

**NOW**

# New (to Sandia) science will help grow current and new SBUs



# Center for Integrated Nanotechnologies (CINT)

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## *Officially...*

- Highly collaborative  
DOE National Facility

Focused on  
nanoscience and its  
integration across  
scientific disciplines and  
multiple length scales.

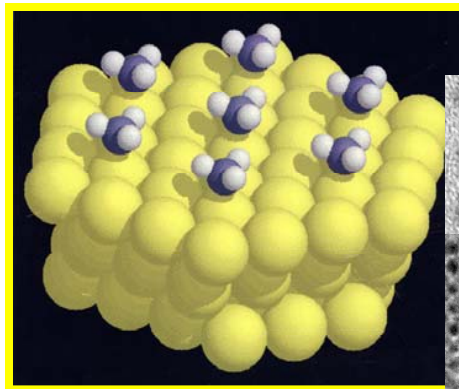
***The Fact is... CINT will be what you make of it!***



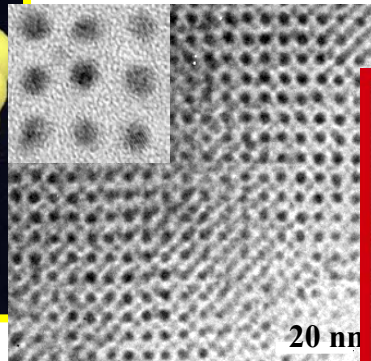
# Vision

## The Center for Integrated Nanotechnologies

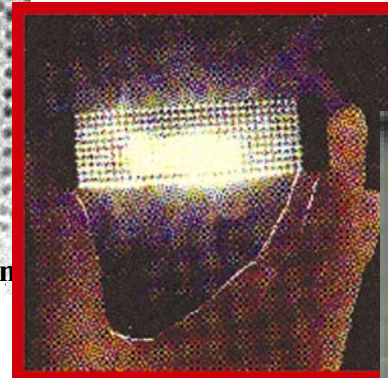
*Exploring the path from scientific discovery to the integration of nanostructures into the micro/macro world*



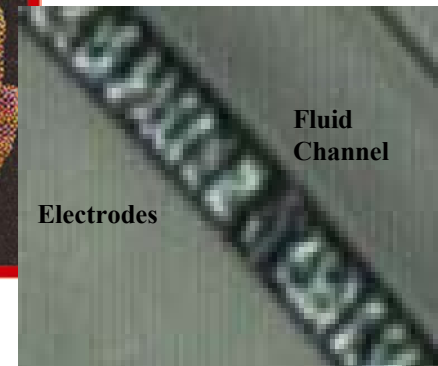
**Theory  
&  
Experiment**



**Synthesis  
&  
Processing**



**Performance**

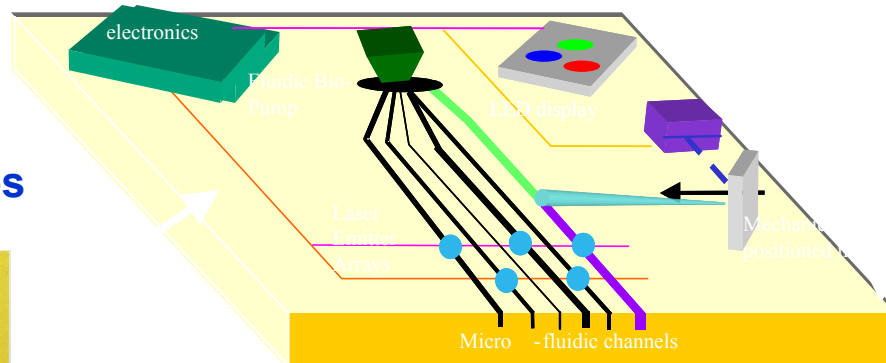
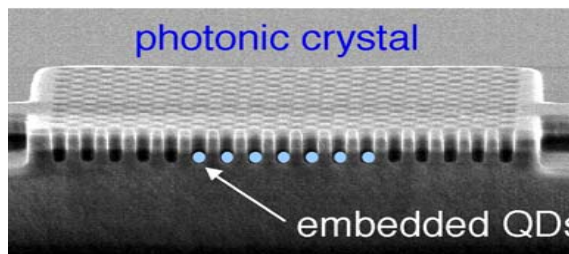


**Integration**

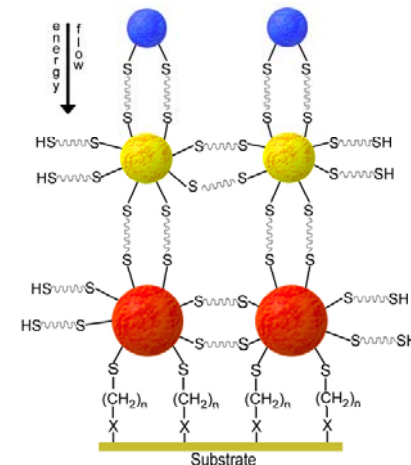


# New nanoscience discoveries will have impact via micro and macro scales

## Nanophotonics/Nanoelectronics



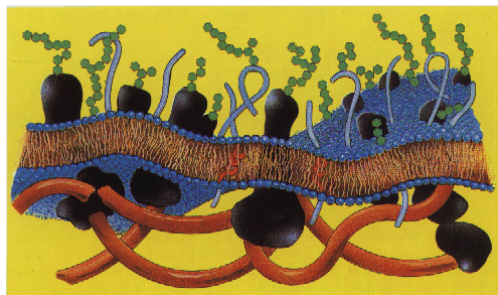
## Complex Functional



## Nanomechanics

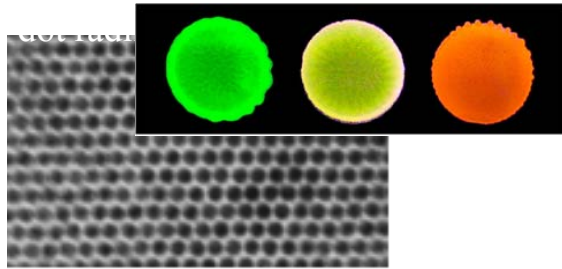


## Nano-Bio-Micro Interfaces

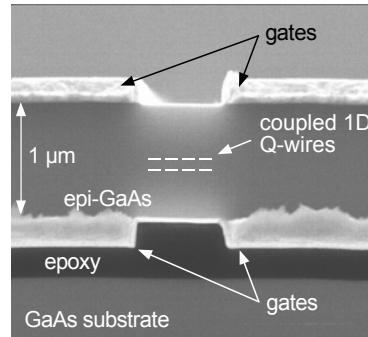


**CINT's scientific thrusts capitalize on the expertise and capabilities of Los Alamos and Sandia**

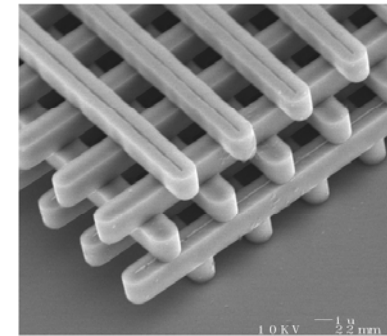
# Nanoelectronics & Nanophotonics: Precise control of electronic and photonic wavefunctions to invoke novel and unique properties



**Tunable electronic  
spectra in Q-dot solids**

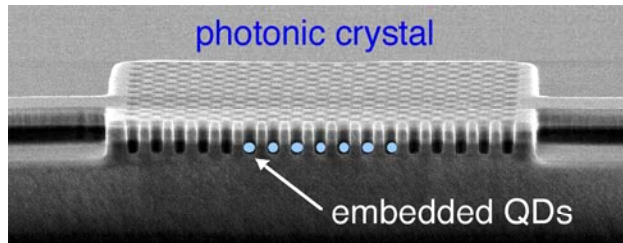


**Correlated states  
in coupled Q-wires**

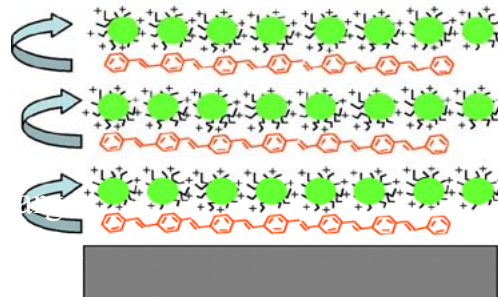


**Tunable photon states  
in photonic structures**

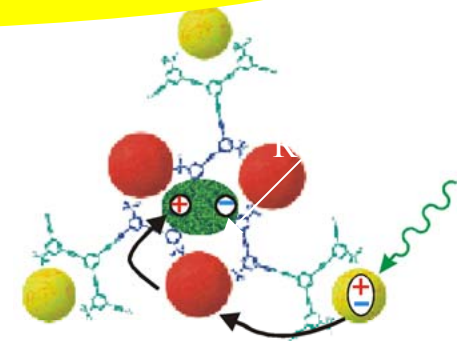
**CINT Focus:** New Phenomena ↔ New Nanoscale Materials



**Interplay between tunable  
electronic and photonic spectra**



**Organic/inorganic  
hybrid structures**

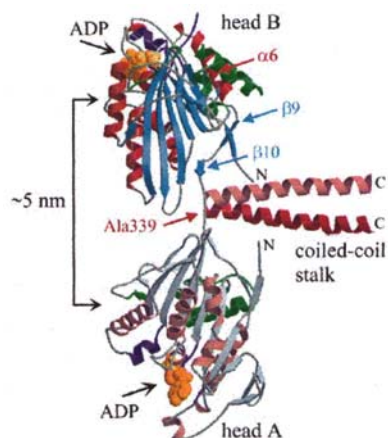


**Bio-inspired  
photonic structures**

# Nano-Bio-Micro Interfaces:

## Biological principles and functions imported into artificial bio-mimetic nano-and microsystems

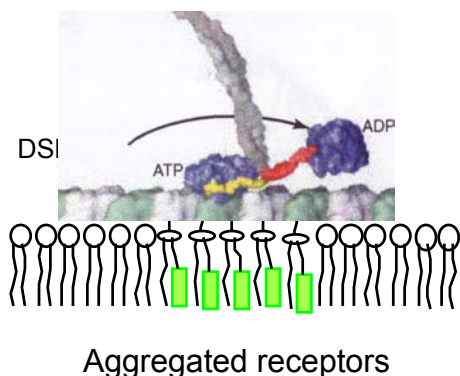
### motor proteins



1-10 nm

molecular biology  
genetic  
engineering

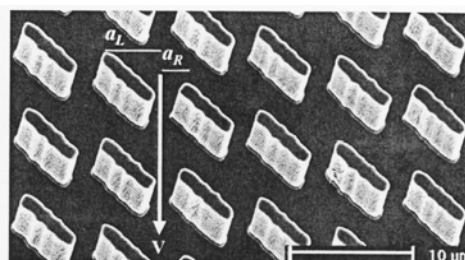
### biomimetic interfaces



10 -100 nm

complexation chemistry  
molecular modeling  
self-assembly

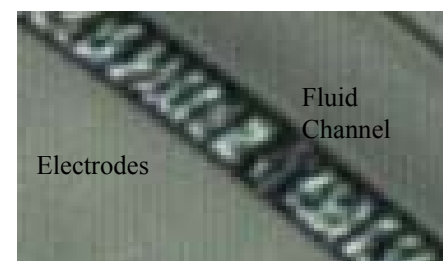
### fiber guides and activation systems



$10^2$ - $10^4$  nm

solid state physics  
microfabrication  
nanomechanics

### microfluidics



$10^5$ - $10^6$  nm

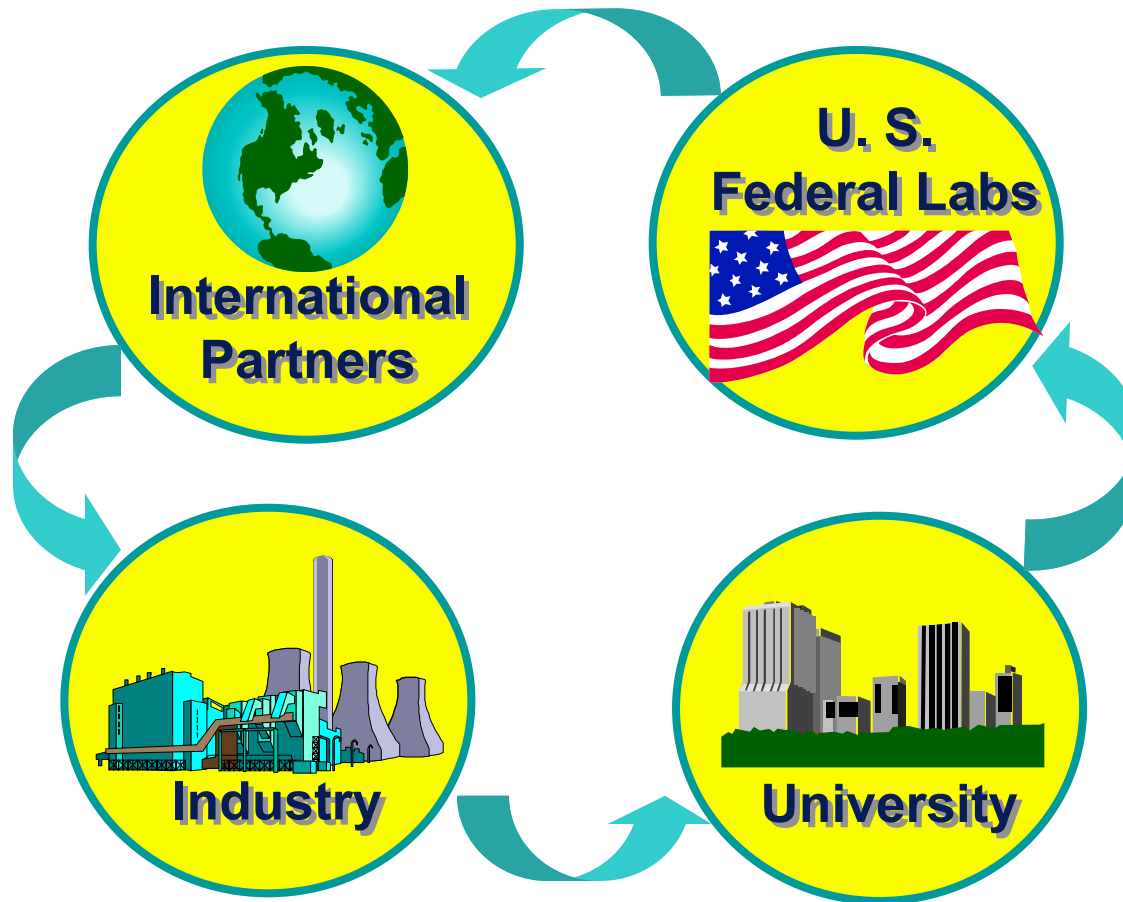
fluid mechanics  
micromechanics  
biochemistry

**CINT promotes the development of tailored nanomaterials and the scientific infrastructure required to integrate such materials into functional systems.**



# A critical success factor for Sandia: developing Strategic Partners

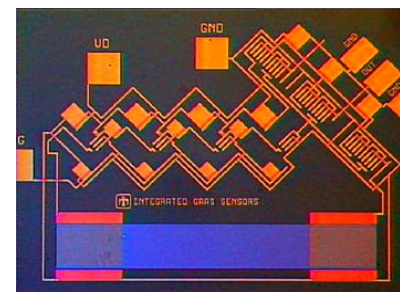
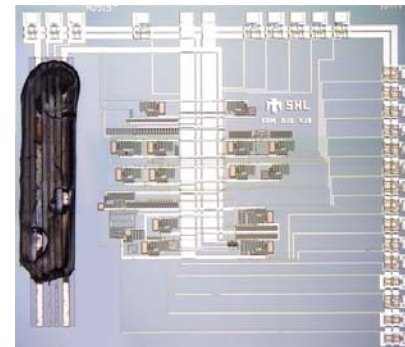
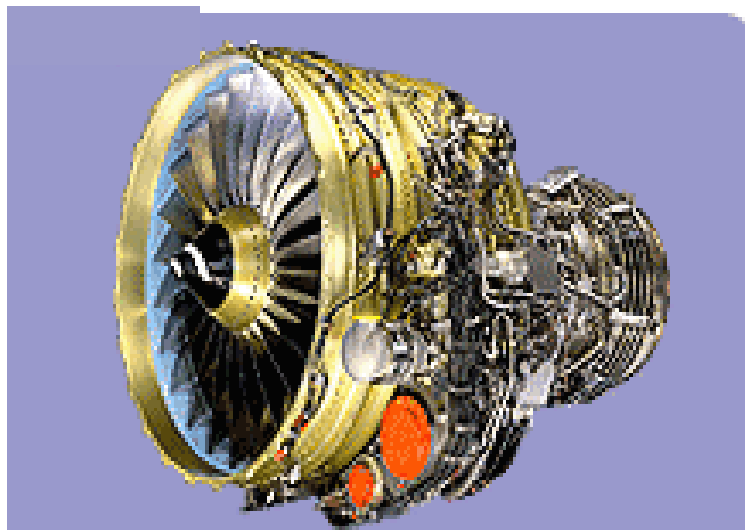
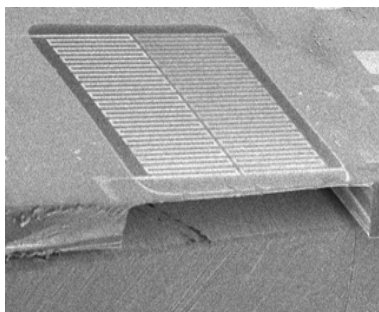
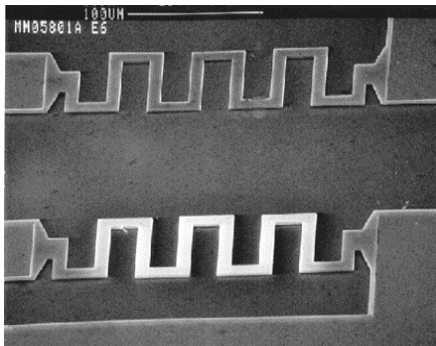
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## Teaming for Success



# Industry partners provide significant S&T challenges



**MICRO-TECHNOLOGIES**



**SYSTEM  
ENGINEERING**



**MICRO-ANALYTICAL  
SYSTEMS for GE &  
SNL APPLICATIONS**



**Sandia  
National  
Laboratories**

# Our strategy for university partnerships...

---

- Focus on a few key campuses
- Build a relationship between our leaders (Campus Executives)
- Understand the nature of our ongoing efforts
- Identify focus R&D areas: seed with internal funding
- Expand and focus our faculty/students/employee programs
- Establish fast-track contracting (As-Ordered Agreement)
- Jointly pursue new opportunities
- Tie R&D to recruiting



# NASA and Sandia Work in Related Technology Arenas to Fulfill Our Respective Missions

## Surety



- Risk Assessment
- Predictive Reliability
- Refurbishment
- State-of-Health Systems
- Advanced Materials
- Smart Structures

## On-Orbit Capability



- Remote Sensing
- Nano/micro satellites
- Rad Hard Electronics
- On-orbit Computing
- Human State-of-Health
- Telemedicine

## Power / Energy

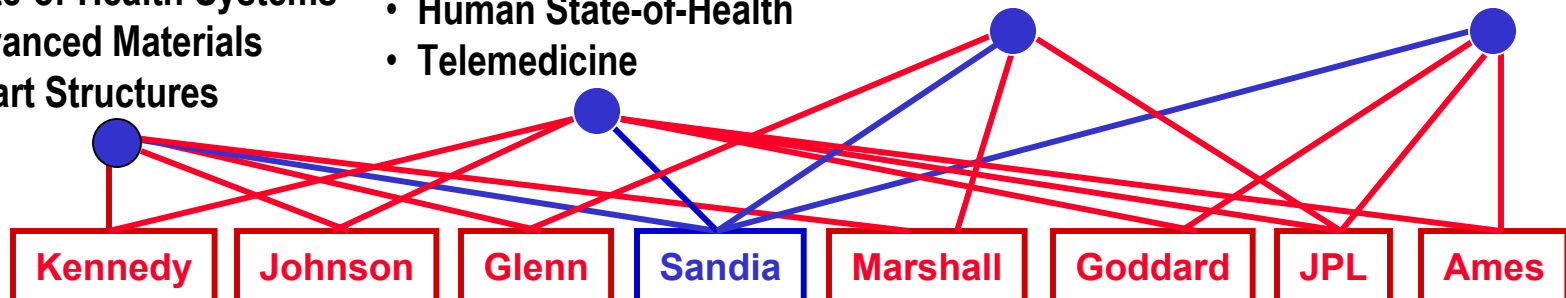


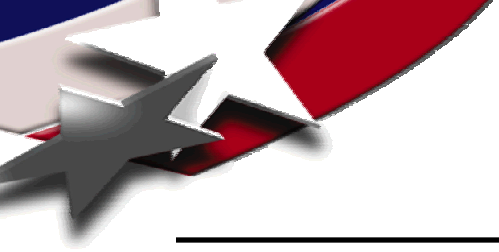
- Combustion Research
- Nuclear Energy
- Advanced Sensors

## Information Technology



- Advanced Computing
- Distributed Computing
- Modeling & Simulation





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# Backup Foils

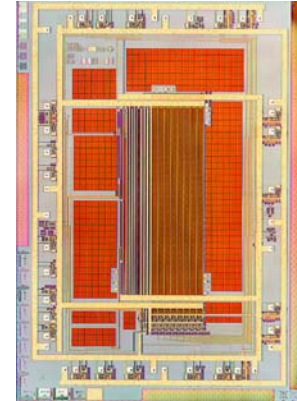


# NASA / Sandia Cooperative Activities Have Been Win-Wins

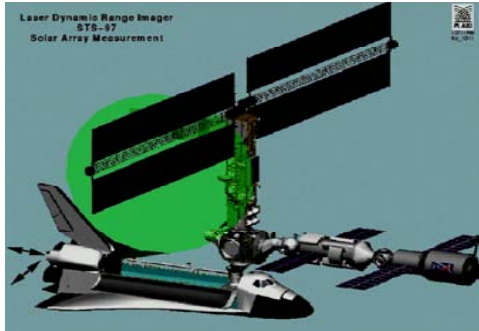


**Mars  
Pathfinder  
Air Bag  
Technology  
(w/ JPL)**

**Radiation  
Hardened  
Pentium  
(w/Goddard  
and JPL)**



**Laser Dynamic  
Range Imager  
(w/JSC)**



**Int'l. Space Station  
Crew Return Vehicle  
(parafoils) (w/ JSC)**



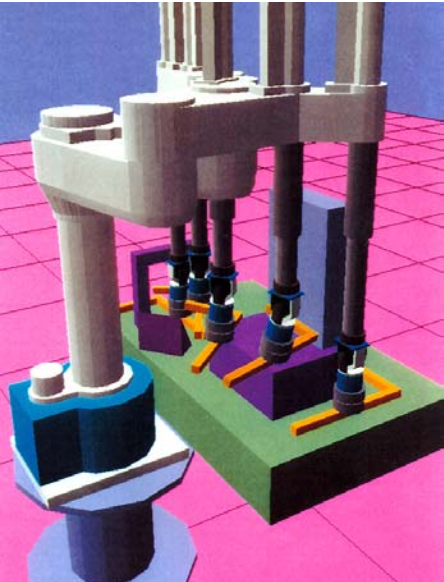
**Thermal  
Protection  
System  
(w/Ames)**

**Aircraft Safety  
and Combustion  
Research (w/Glenn)**

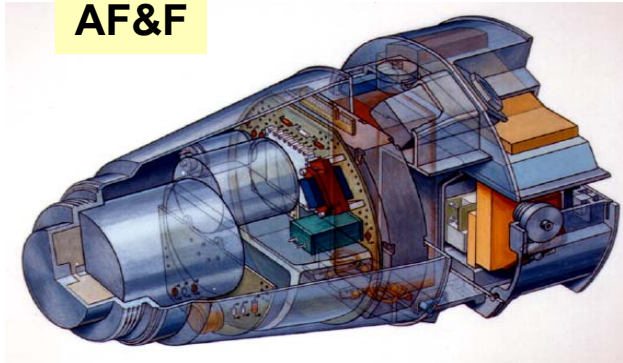


# Computational and Information Sciences support a wide range of applications

Intelligent machines



AF&F



Large scale, massively parallel computing resource



Architecture Layer Functionality

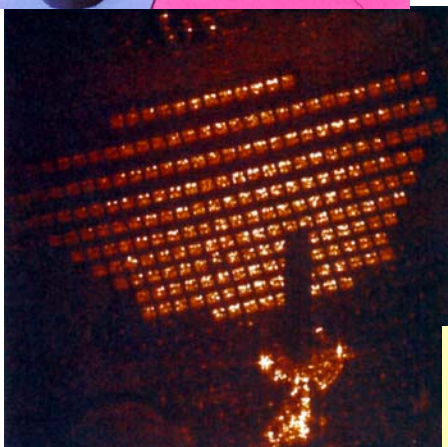


**DisCom<sup>2</sup>**  
Distance Computing and  
Distributed Computing

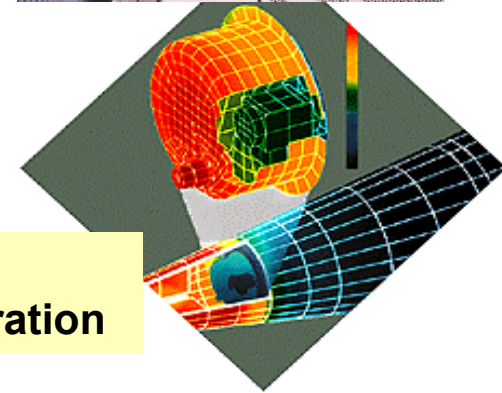


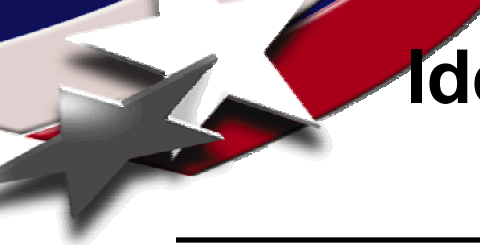
Information Systems

Image  
processing



Mesh  
generation





# Identified Areas of Mutual Interest (NASA/SNL)

---

♦ Radiation Hardened Electronics (e.g. Pentium)	JSC, JPL, Goddard, Langley, Glenn
♦ Design Paradigm/Revolution in Engineering & Manufacturing	JPL, Ames
♦ Neural Nets and 3 DANN Cube	JPL
♦ Sensors, Microsensors, Systems-on-a-chip (SOAC) MEMS, In-situ Measurement	JPL, JSC
♦ Nanostats/Microsat Technology	JPL, JSC
♦ High Integrity Software	Ames, JPL
♦ Robotics	JSC, Ames
♦ Data Compression for High Frequency Space Communication	Glenn, JPL



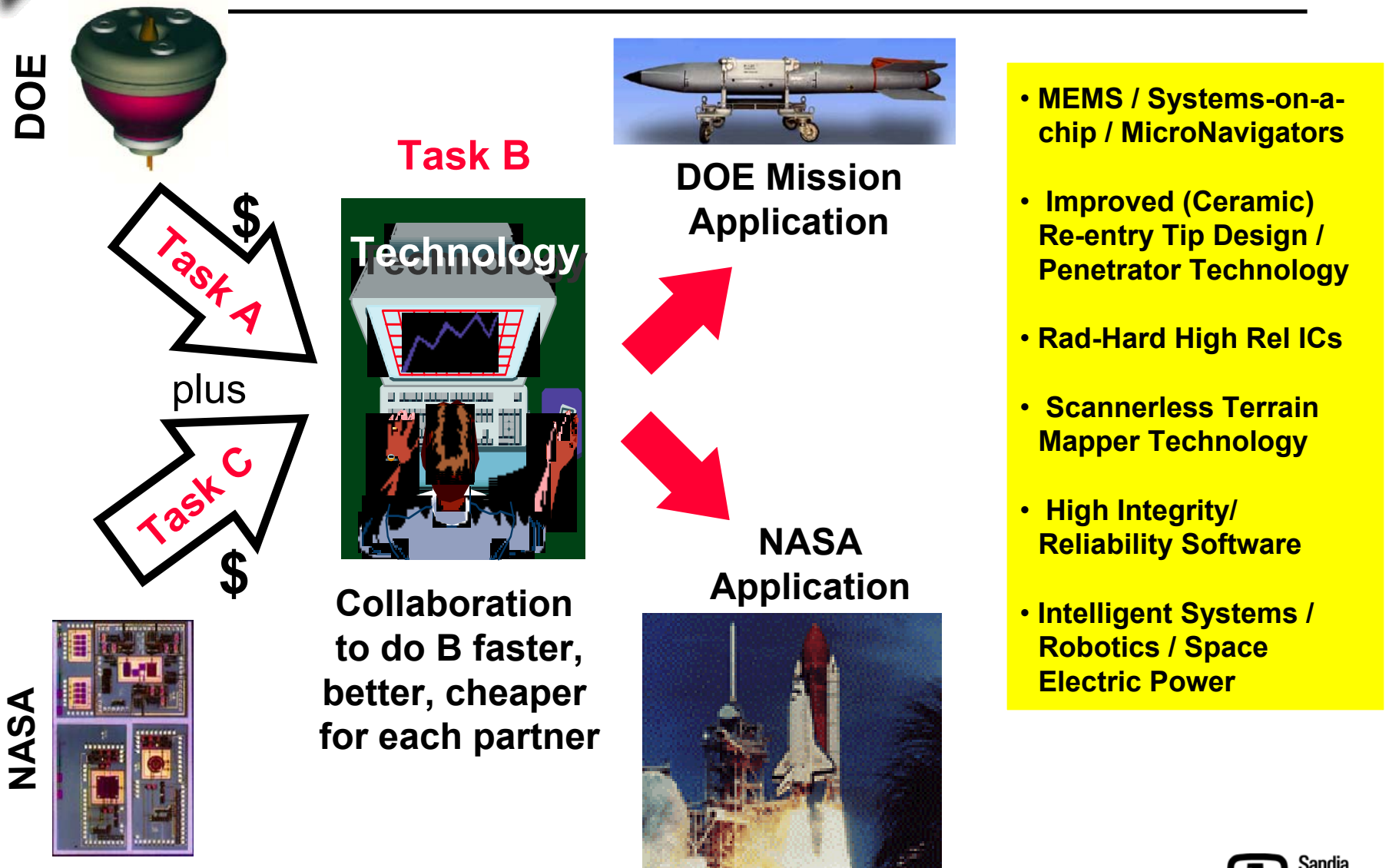
# Identified Areas of Mutual Interest (continued)

---

- |  |            |
|--|------------|
| ◆ Virtual Reality/Artificial Intelligence                  | JSC, JPL   |
| ◆ Advanced Manufacturing, Rapid Prototyping                | JSC        |
| ◆ Sub-surface Explorer, Penetrator                         | JPL, JSC   |
| ◆ Micro-Navigational Aids (MEMS-based IMU's)               | JPL, JSC   |
| ◆ VCSELs, Non-volatile memories, mixed mode ASICs          | JPL, Glenn |
| ◆ ChemLab-on-a-Chip, Environmental Sensors                 | JSC, JPL   |
| ◆ Proximity Sensors, Collision Avoidance Sensors, Robotics | JSC, JPL   |



# Win-Win Partnerships Model



# Sandia's Nuclear Weapon components and subsystems will benefit from the availability of microtechnologies

**“Weaponization” - - Design, engineering, testing, integration, and production interface for non-nuclear components**

## Components/Subsystems

Neutron Generators  
Arming/Safing System  
Fuzing System  
Firing System  
Use Control System  
Gas Transfer System  
Power Supplies  
Energetic Components  
Electronics (Digital/Analog)  
Structures & Packaging  
Parachutes  
Use Control Equipment  
Test & Handling Equipment



**W88/MK5**

Arming, Fuzing, and  
Firing System

Total parts > 3000



**B83 Strategic Bomb**

**Total parts - 6,519**

- Sandia developed - 3,922
- Sandia specified - 2,378

***All parts must come together  
to form a high-rel system***

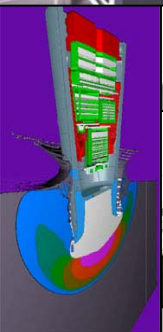


# Mesa Complex

# Components



## System Engineering

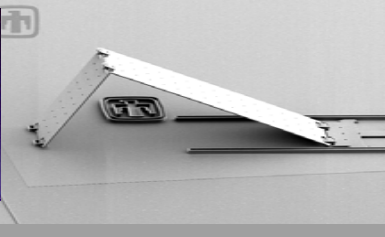
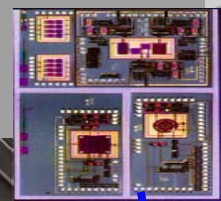


**MESA is the Cornerstone of our Strategy to Meet our Mission Needs**

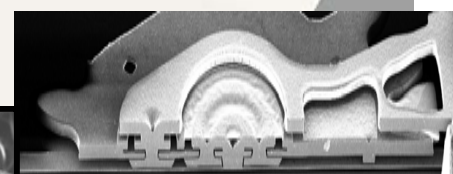
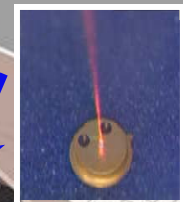
**Construction: \$58M**  
**Equipment: \$12M**

**TOTALS:** Construction: \$198M, Equipment: \$150M  
Contingency & Escalation: \$75M, TEC: \$423M

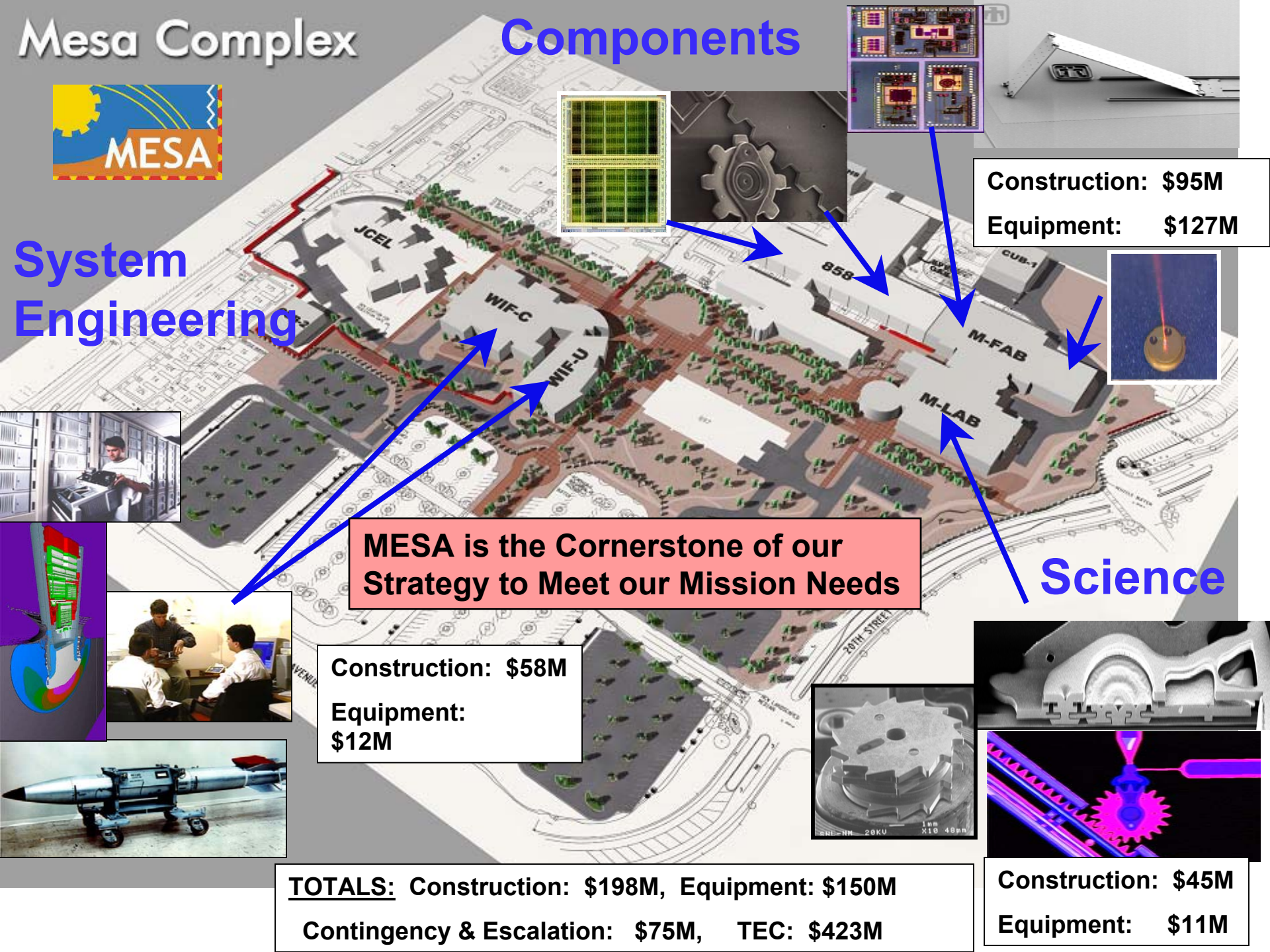
## Science



**Construction: \$95M**  
**Equipment: \$127M**

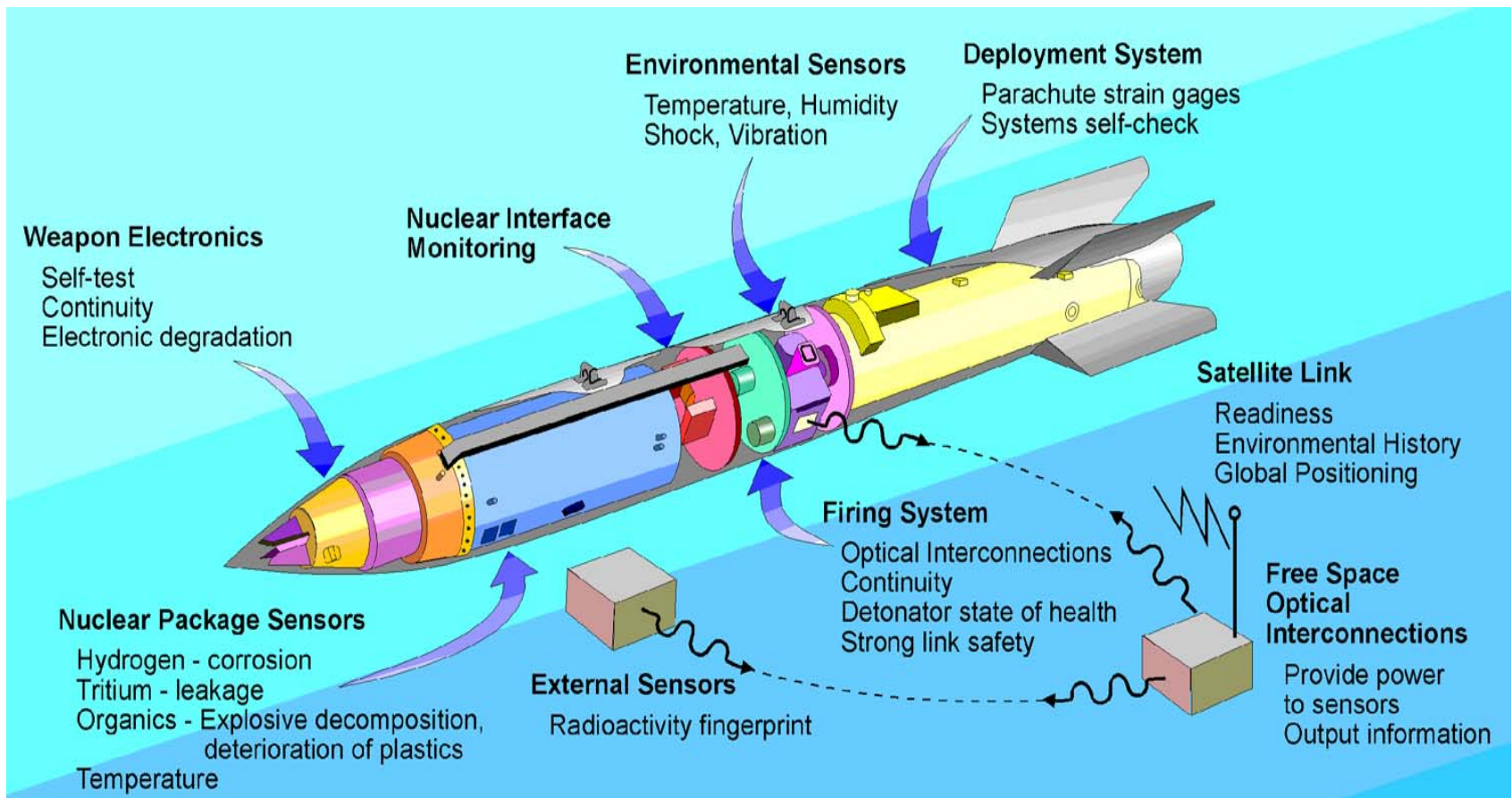


**Construction: \$45M**  
**Equipment: \$11M**



# Sandia's Science-Based NW Product

Weapons that are inherently safe, know where they are at all times, diagnose and communicate their state of health and location, are tamper proof, cannot be armed until they have located their target, will not detonate until they have received and verified the fire command, and are reliable without underground testing

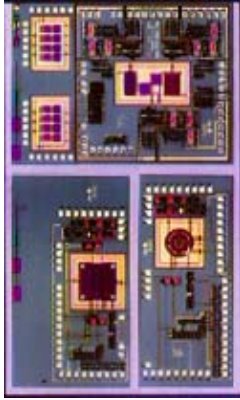






# Three Integrated Microsystems are Under Development

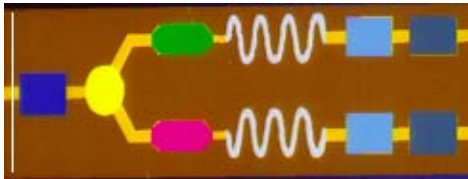
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## **Micronavigator**

A collaboration with  
UC Berkeley)

**Weapon guidance, weapon  
fuzing, commercial  
applications: e.g. air bags**



## **Chem Lab-on-a-Chip**

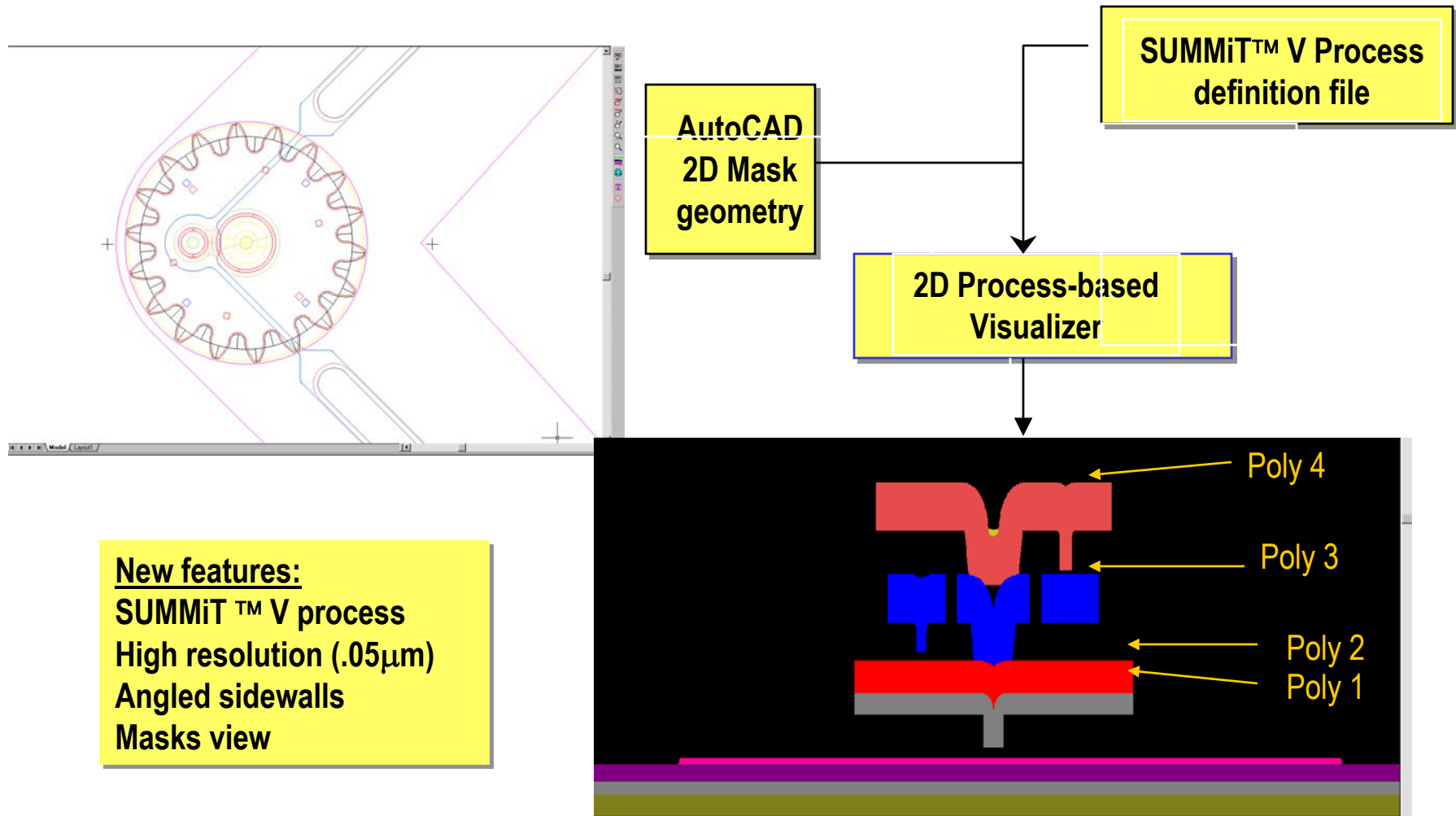
**Weapon state-of-health,  
non-proliferation,  
counter-terrorism**



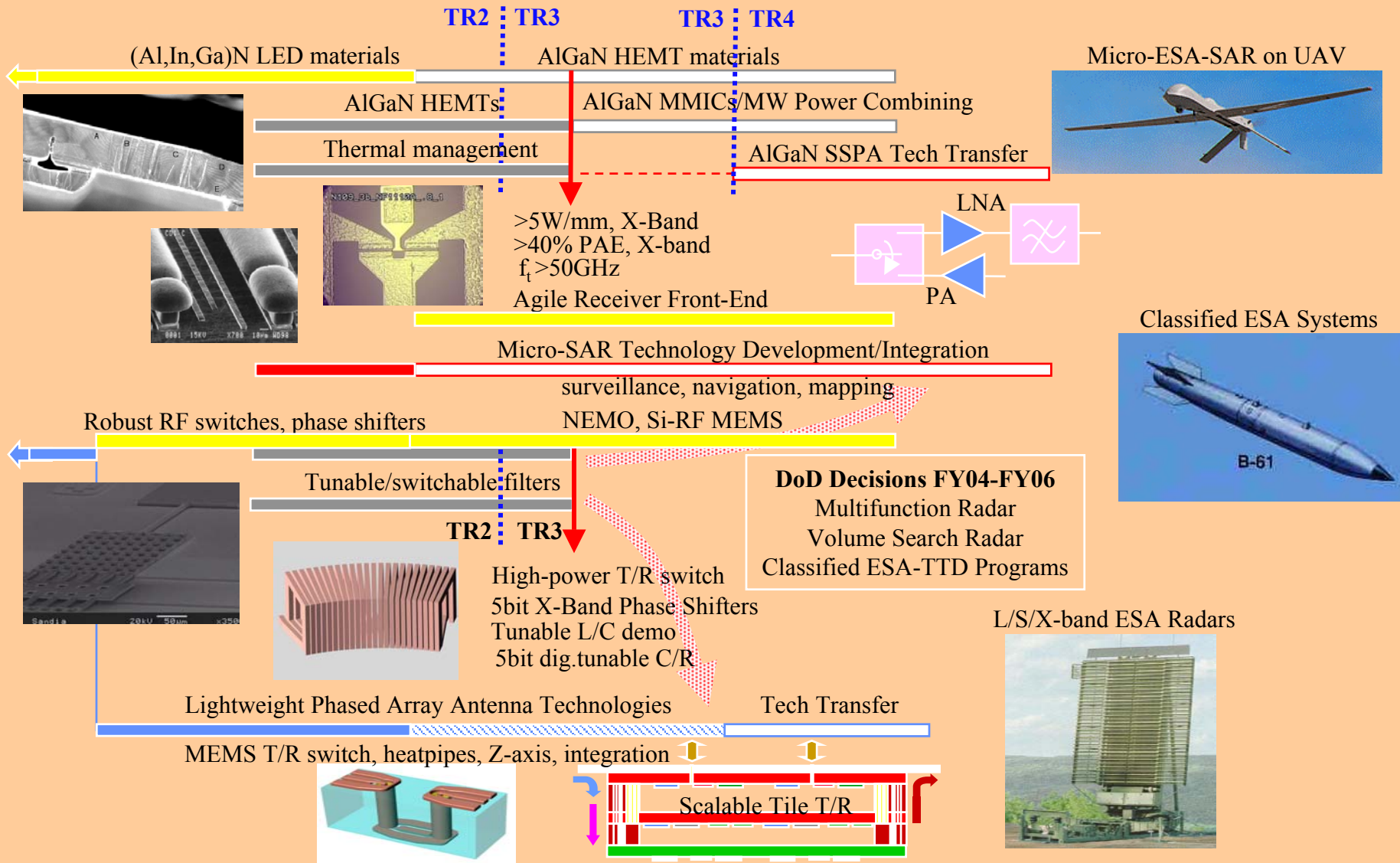
## **Micro-surety Device**

**Weapon surety, protection  
of high value assets**

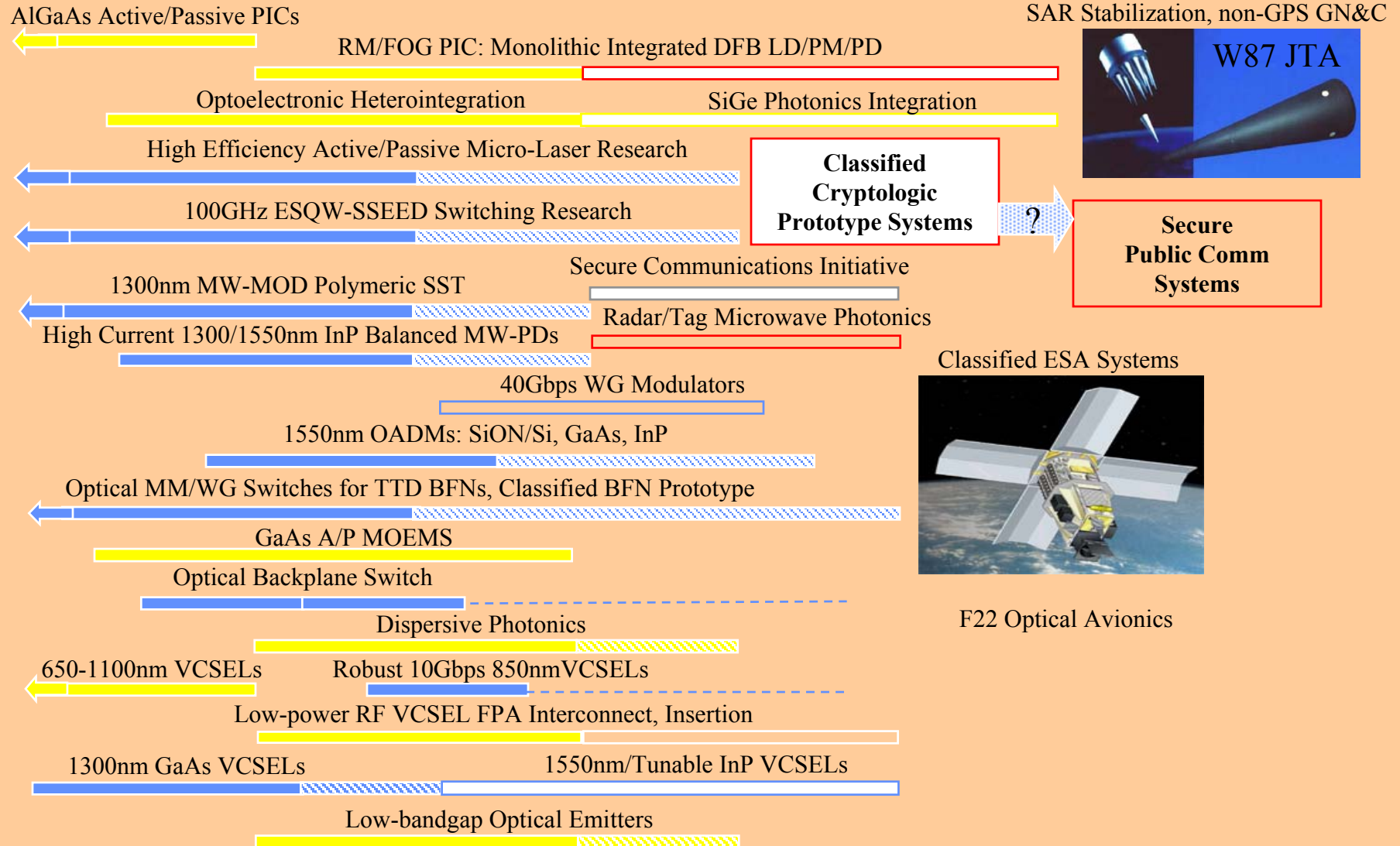
# 2D Process Visualizer - process flow



# RF Microsystems Technologies Roadmap: Micro-SAR Technologies



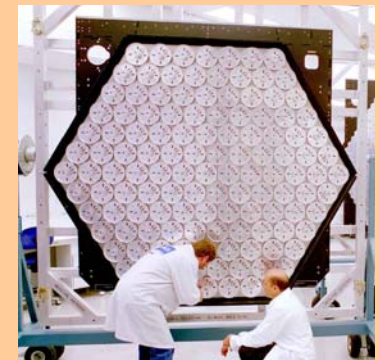
# RF Microsystems Technologies Roadmap: Photonics Communications







## ESA Satellites



## NW Refurbishment

